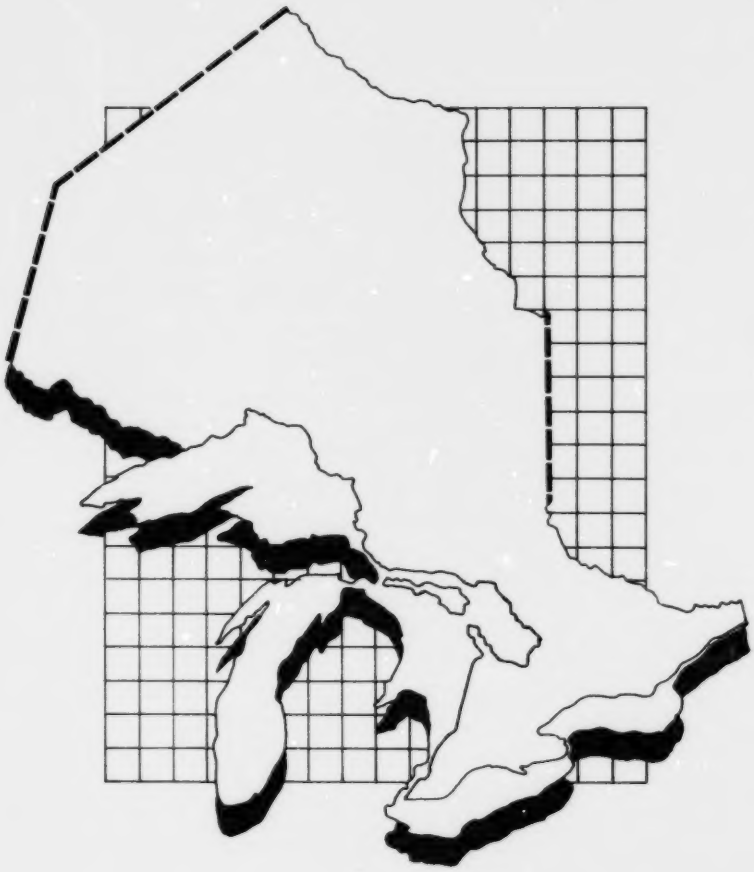
Climatic Information for Energy Conscious Planning



Ontario

Ministry of Energy

Honourable Robert Welch,Q.C. Minister

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CLIMATIC INFORMATION

FOR

ENERGY CONSCIOUS PLANNING

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ABSTRACT

This report has been prepared to assist planners and designers in creating a built environment that responds to climatic conditions. The information provided should facilitate a reduction in energy consumption in buildings and developments which have incorporated the key recommendations found here.

The nature and influence of such climatic factors as solar radiation, air temperature, wind and humidity are reviewed and techniques to apply these theories to a variety of land uses are proposed. This report brings into focus both long-held and rarely considered theories relating to the effect of different environmental factors on energy consumption and provides data to corroborate its findings. The greatest energy savings, it was found, can be realized through appropriate solar orientation and the maintenance of solar access. Design and construction with regard to air temperature and prevailing winds have also been demonstrated to have a significant impact on energy consumption.

The report concludes that if development is designed and built with a sensitivity to local climatic conditions, the potential for energy savings will be enhanced and our living environment improved.

Introduction

Energy Use and the Climate

Man has had to combat the elements since he first encountered them. He has had to protect himself from the heat of summer, the cold of winter, wind, rain, and snow with whatever tools were available. A roof, four walls, ventilation and a heating system were among the first human contrivances to protect man from the elements.

Urbanization and scientific development have affected both the climate and the means available to ensure human comfort in the twentieth century. We can now both predict the season's climate and adapt our living and working spaces to maintain a constant temperature and humidity regardless of the outdoor phenomena. We can measure the degree and intensity of climatic changes (wind, precipitation, heat, cold, and humidity) and thereby estimate the amount of mechanically created energy needed to bring indoor conditions to a comfortable level. Moreover, building planners can take climatic influences into account before construction begins and thus minimize future energy consumption by the placement of the structures with regard to the influences of wind, sunlight, and slope.

These developments have become essential in the face of soaring energy costs and predicted shortages of conventional fuels. Climatologists are being asked more and more to work with planning professionals to consider all aspects of climate when planning their building projects. Far sighted planning is particularly crucial in urban areas where the lion's share of our conventional energy resources are consumed. This report then, is aimed for the most part at urban planners and developers in both the private and public sector to familiarize them with the data available for making urban growth and redevelopment in the future energy-efficient.

The report was commissioned by the Ontario Ministry of Energy to specifically deal with questions related to Ontario's climate and energy use. Comparisons and likenesses, however, can be drawn between this province and other areas. Hence, the studies done for the report could prove useful for planners outside the provincial boundaries.

Ontario's climate is far from uniform. The northern and southern areas differ greatly. The report shows both the causes of these differences (Arctic winds versus Gulf of Mexico air currents, the Great Lakes, latitude, and sunlight) and provides an explanation of the specialized energy needs of each area.

Every conceivable aspect of development has an effect on the climate of an urban area and the comfort of its inhabitants. This report shows how tall buildings downwind from smaller ones affects the the wind velocities and strength, for example. Or how buildings located in depressions, where cool air pools, such as those at the bottom of slopes will increase the need for winter heat. It discusses how to maximize the hours of direct sunlight through window placement. In examining the effect of green space on the surrounding climate, it corroborates the aesthetically founded inclusion of parkland and lawns in urban developments; it examines how ground surface temperature is affected by landscaping, and the important role of evaporation and transpiration in cooling an urban area in the summer. All types of vegetation are examined for their influences--from grassy areas to coniferous forests.

The report further gives information about the tools used by climatologists to measure and document the climatic variations in any given area. Climatological stations throughout the province gather and record the information. These stations range in sophistication from the smaller weather stations which record only the most basic climate information of temperature, wind, precipitation and humidity to the more established facilities which also have equipment for measuring various types of solar radiation, bright sunshine, and pollution. This equipment and the methods for utilizing it is explained in layman's terms.

The difficulties confronting planners wishing to initiate innovative and energy-conscious designs are examined realistically in this report and solutions suggested. The planner must often work within the limitations of already built streets, for example. As well, initial hesitations towards changes in the norm must be overcome, and rapport with elected officials must be established to effect any changes in legislation necessary to implement the energy-conscious designs.

The authors of this report have created it to be a handbook for gathering information. Much of the data, they concur, available to them at the time of writing is somewhat out of date and planners should use the report as a foundation for gathering current climatic information on proposed building sites rather than as a complete text. The glossary explaining key phrases used by climatologists and the full list of reference material (both located at the back of this report), are in keeping with their stated purpose.

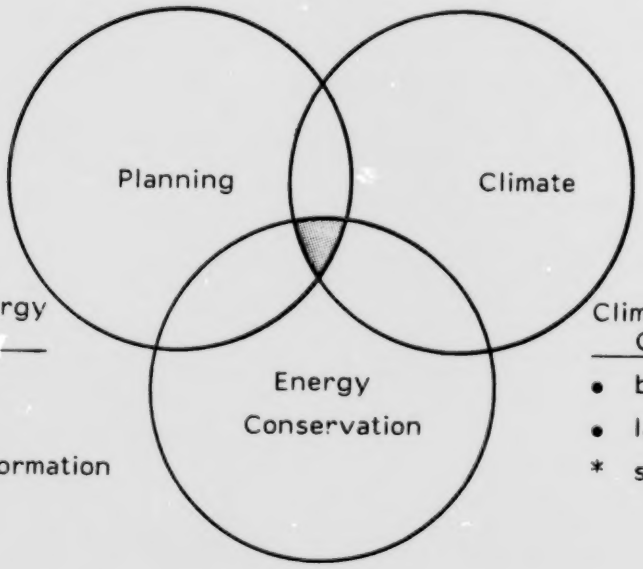
Nonetheless, the information presented here should be of great value to municipal planners. Data gathered from a variety of specialized sources have been brought together to provide the planners with both the technical and theoretical information on climate and the application of climatic data in planning to reduce energy consumption. Information relating to the three areas of climate, planning, and energy conservation, has, to date, been rarely seen in one document.

FIGURE 1.1

RELATIONSHIP OF PLANNING, CLIMATE AND ENERGY CONSERVATION

Planning and Climate

- wind in pedestrian areas
- outdoor comfort levels
- parks planning
- limited information



Planning and Energy Conservation

- transportation
- urban form

* substantial information

Climate and Energy Conservation

- building design
- landscape practice

* substantial information

Planning, Climate and Energy Conservation

- solar orientation of buildings
- urban heat islands
- placement of barrier buildings
- locate residential development on south slopes.

** very little information

Climate: A Brief Overview

2.0 CLIMATE: A BRIEF OVERVIEW

Our climate is shaped by many factors including solar radiation, wind, temperature, evaporation, precipitation and temperature differentials. The interaction of these factors develop weather systems which are influenced locally by variations in landforms and the presence of large areas of open water. These conditions create a reasonably predictable regional climatic regime as well as more localized climates.

This chapter will provide a basic understanding of these climatic factors, their interrelationship and influence on the environment. The variations in these factors caused by changes in the land surface (i.e., vegetation, water, urban development, etc.) will also be discussed.

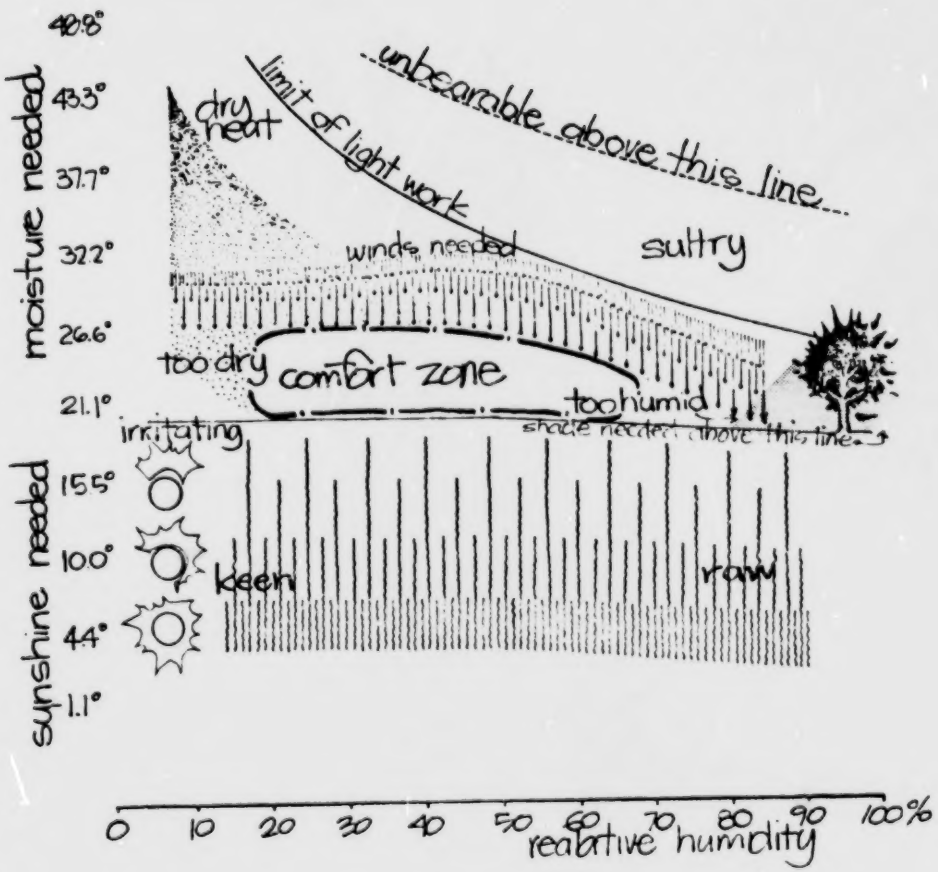
2.1 Climatic Factors

The interaction of solar radiation, wind, air temperature and humidity creates a variety of climatic conditions. We dress ourselves, design our buildings and alter our environments in response to these conditions and to maintain an acceptable level of human comfort. It is essential that designers (of clothes, buildings or towns) consider human comfort and understand how the human comfort zone can be modified by climatic factors. This is illustrated graphically in Figure No. 2.1. This schematic diagram of the Bioclimatic Chart is applicable to inhabitants of the moderate climate zone of North America at elevations less than 1000 feet above sea level. As pedestrians in the downtowns of large cities are aware, to their discomfort, urban development can change climate adversely by creating environments that encourage windspeed and reduce temperatures through shading.

The comfort zone for a person sitting outside in the shade is shown in the centre. Any climatic condition can be located on the chart by plotting the dry-bulb temperature and the relative

FIGURE NO.2.1

SCHEMATIC OF THE BIOCLIMATIC CHART



humidity. Should this point lie outside the comfort zone then the climate must be modified by moisture, wind or sunshine to make it comfortable. The schematic illustrates which factors should be modified. In many cases, the desired climate can be achieved by natural means involving design to utilize climatic elements. Severe conditions must be corrected by mechanical means such as air conditioning and heating.

It should, however, be an objective of all designers to make the utmost use of the natural means available in order to produce a more healthful environment and to achieve a saving in cost by keeping to a minimum the need for mechanical aids for climate control.

The basic climatic factors, solar radiation, wind, temperature, humidity and percipitation are briefly discussed in the following sections.

2.1.1 Solar Radiation

Solar radiation is that energy from the sun which arrives at the Earth's surface in the form of electromagnetic waves (wavelengths between 0.15-3 microns). The amount of energy available at the earth's surface depends on a variety of atmospheric and surface factors. Figure 2.2 illustrates the important control the atmosphere and particularly clouds have in determining the amount of solar radiation reaching the surface. Since maximum solar energy is received when the sun's rays are perpendicular to the surface (Figure 2.3), latitude and slope are important controls. For instance, horizontal surfaces receive maximum energy in the tropics whereas south facing slopes receive energy in the mid-latitudes. (Figure 2.4). A final important surface control on solar radiation is the albedo or the ability of the surface to reflect solar radiation. Table 2.1 shows the albedo of many common surfaces. Surfaces

that appear bright are reflecting large amounts of solar radiation (i.e., snow) whereas those that are dark (i.e., dark wet soils) absorb large amounts of solar energy.

FIGURE NO.2.2

LOSSES OF INCOMING SOLAR ENERGY
BY SCATTERING, REFLECTION, AND ABSORPTION

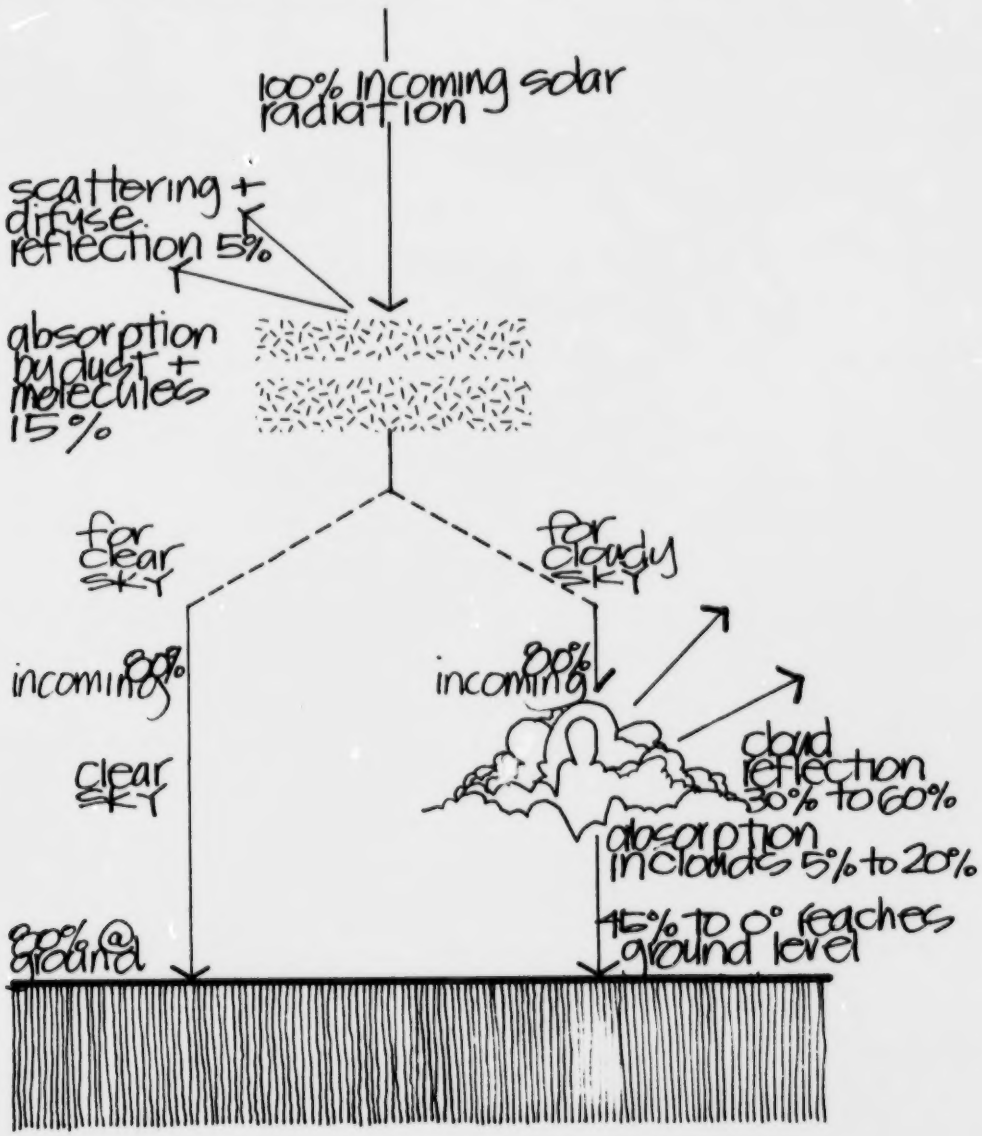
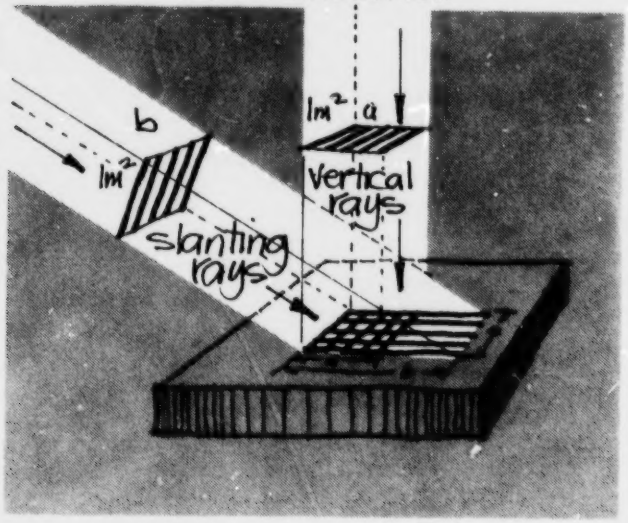


FIGURE NO.2.3

EFFECT OF SUN ANGLE ON INTENSITY OF SOLAR RADIATION



The angle of the sun's rays determines the intensity of isolation on the ground. The energy of vertical rays "A" is concentrated in a square 'a', but the same energy in the slanting rays "B" is spread over a rectangle, 'b'.

(Strahler, Strahler, 1978)

FIGURE NO.2.4

EFFECT OF LATITUDE AND SLOPE ON SOLAR RADIATION AT SEPTEMBER 21, AND MARCH 21.

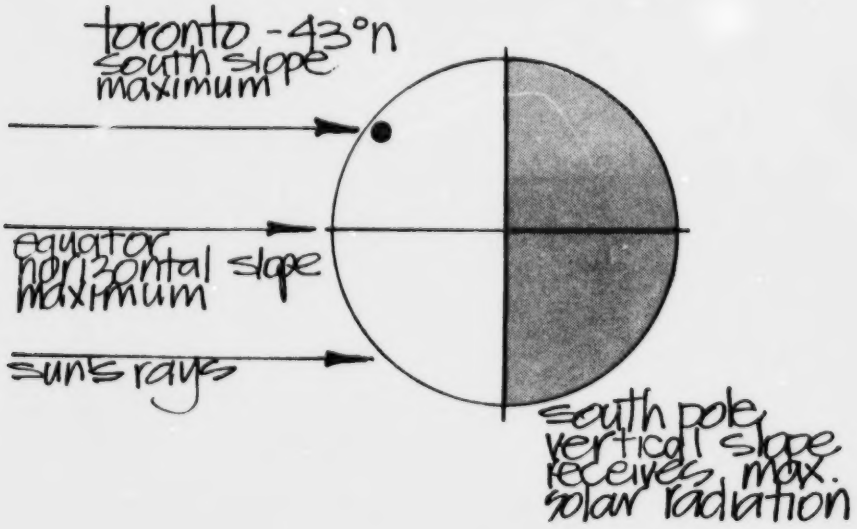


TABLE 2.1

ALBEDO OF VARIOUS SURFACES

Surface	Remarks	Albedo
Soils	Dark, wet Light, dry	0.04- 0.40
Desert		0.20-0.45
Grass	Long (1.0 m) Short (0.02 m)	0.16- 0.26
Agricultural crops, tundra		0.18-0.25
Orchards		0.15-0.20
Forests		
Deciduous	Bare Leaved	0.15- 0.20
Coniferous		0.05-0.15
Water	Small zenith angle Large zenith angle	0.03-0.10 0.10-1.00
Snow	Old Fresh	0.40- 0.95
Ice	Sea Glacier	0.30-0.45 0.20-0.40

Source: Colle, 1978.

According to Table 2.1, a fresh snow surface will reflect 95% (.95) of the solar radiation impinging on it and a dark wet soil will reflect only 5% of this incoming solar energy. Since more heating occurs when albedos are low, these surfaces are generally the warmest.

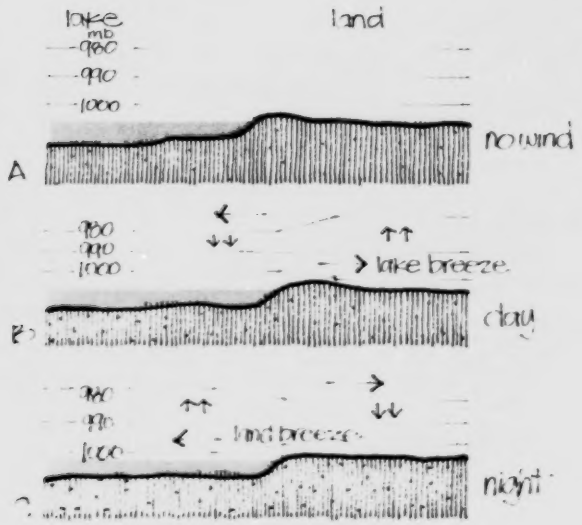
2.1.2 Wind Speed and Direction

Winds are important because they influence the heating demand in the winter and have potential for natural ventilation in the summer. Wind is caused by differential heating of the earth's surface which results in pressure differences. Winds can be thought of as the

atmospheres' attempt to equalize these pressure differences. Therefore, winds flow from regions of higher pressure toward areas of low pressure, as Figure 2.5 illustrates for a Lake/Land breeze. Over the land, rapid heating of the lower atmosphere by day causes the isobars (lines of equal pressure) to diverge, therefore causing the circulation show in B. Rapid cooling by night over the land surface causes a breeze to flow in the opposite direction.

FIGURE NO.2.5

LAKE BREEZE AND LAND BREEZE



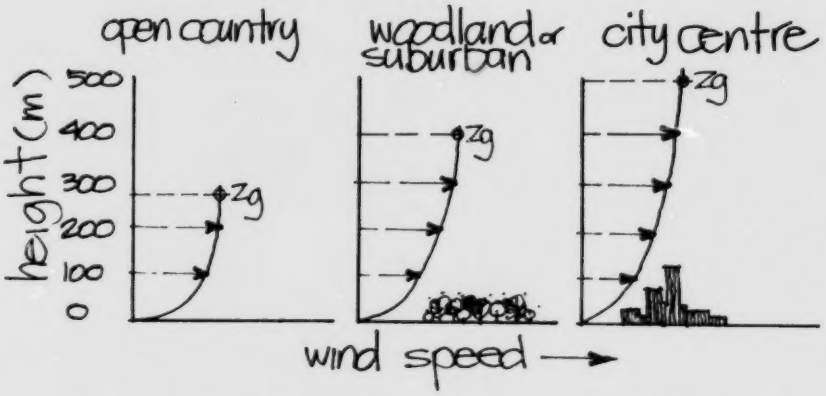
(Strahler, Strahler, 19)

Near the earth's surface, the wind speed is controlled largely by the frictional drag of the surface.

As Figure 2.6 demonstrates, rougher surfaces, create slower winds in the lower atmosphere (Zg refers to the elevation above which surface effects <u>are not</u> noticeable).

FIGURE NO.2.6

WIND SPEED CHANGES WITH
VARIATIONS IN SURFACE ROUGHNESS



(Oke, 1978)

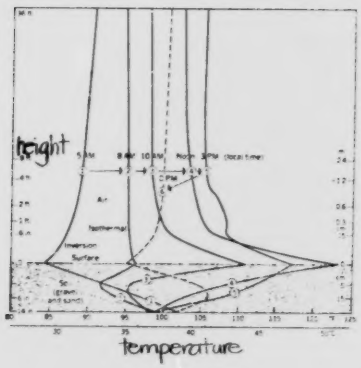
Wind speed also has a diurnal variation, faster by day, slower in the evening. This is due to daytime surface heating which mixes faster flowing air aloft with slower moving surface air.

2.1.3 Air Temperature

Diurnal temperature variations near the surface are considerable, as illustrated by Figure 2.7. The surface undergoes the widest variations whereas the overlying atmosphere and soil remain more conservative in their fluctuation. Near the ground, wide variations in temperature occur and this is even more pronounced as surface types change (i.e., pavement or parkland) or as slope changes (south slopes vs north slopes).

FIGURE NO.2.7

AIR AND SOIL TEMPERATURES AT VARIOUS LEVELS
ABOVE AND BELOW THE GROUND SURFACE
THROUGHOUT THE DAY AND NIGHT



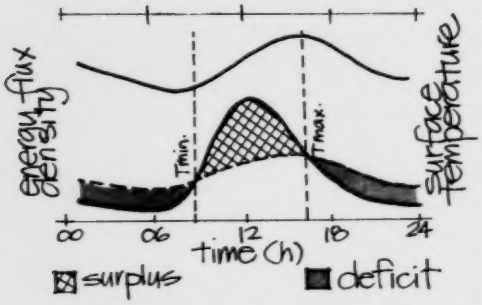
(Stahler, Stahler, 1978)

Data are averages for July and August during a single summer. Height follows a square-root scale. (Data from Quartermaster Research and Development Branch, U.S. Army).

This variation in temperature, shown in Figure 2.7, is due to the diurnal pattern of inputs and outputs of radioactive energy at the earth's surface (Figure 2.8). During the day, more energy arrives than is lost, therefore, causing increasing temperatures. In the evening, more energy is lost than arrives at the surface, causing temperatures to decline. Minimum temperatures occur just after sunrise, since cooling has continued throughout the night.

FIGURE NO.2.8

THE RELATIONSHIP BETWEEN SURFACE ENERGY AND THE DIURNAL SURFACE TEMPERATURE REGIME

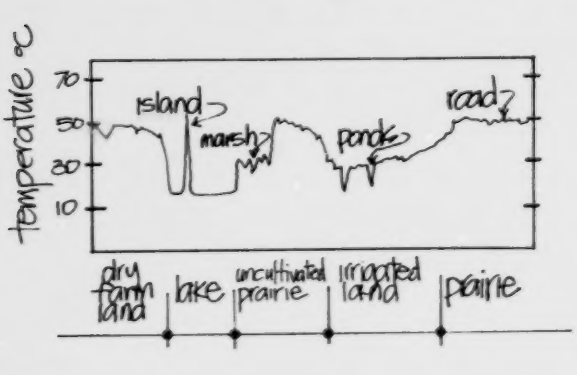


(Oke, 1978)

Different surfaces, through variations in their reflectivity or albedo, soil moisture content, slope and aspect and a host of other factors, create contrasting microclimates. Figure 2.9 shows the wide changes in temperature from 50°C to 20°C, for a prairie landscape. These microclimates can be advantageous if planners utilize favourable microclimates and avoid those which are not compatible with reducing building energy use.

FIGURE NO.2.9

CHANGE IN SURFACE TEMPERATURE FOR A PRAIRIE LANDSCAPE



(Oke, 1978)

2.1.4 Humidity

Relative humidity is a measure of the water vapour in the air as a percentage of the total amount of moisture the air can hold at a given temperature. As relative humidities undergo large diurnal variations it is recommended that the value of relative humidity near the time of maximum temperature be used as the best indicator of the potential for evaporative cooling rather than the average daily humidity. The maximum daily temperature occurs at approximately 1500 LST (local standard time).

2.1.5 Precipitation

Precipitation comes in a variety of forms from the liquid to the solid state. The volume and distribution of precipitation will be of interest to planners and will influence urban planning as it relates to flood control and areas for snow storage. With the exception of periodic hail storms, freezing precipitation is possible from December through April.

Precipitation in the form of rain will influence both land surface and air temperatures by producing prominent reductions. Relative humidity will often rise after rain showers.

The location and intensity of precipitation will vary according to the nature of the weather system as well as local topography and bodies of water. These local factors will form part of a discussion of meso and microclimates (see Section 2.3).

2.2 Climatic Variation

There are three distinctive scales of climatic patterns. The largest are regional in nature and can be 2000 km in diameter. The second scale is called a mesoclimate and may influence only a single town, valley or mountain. Smaller still are microclimates, so limited they affect only a small area, perhaps a farm field, grove of trees or a sidewalk.

Microclimates are very susceptable to changes in the surfaces that create them. All surfaces, both natural and man-made, have different thermal, moisture and radioactive characteristics and consequently produce different microclimates. Pave a grass area or shade a pathway and the microclimate will change accordingly. The elements that make up microclimates are presented in Table 2.3.

As urban areas increase in size they will exert a greater influence on the regional climate and expand the possibility of creating meso- and microclimatic conditions.

The main microclimates, often referred to technically as micro-environments, of interest to the land use planner, are those related to changes in the land surface. These can be grouped in the following categories:

- vegetated surfaces
- water surfaces
- land forms
- urban surfaces

The main characteristics (temperature, wind and humidity) as well as the processes which produce these microclimates are presented in the following sections.

TABLE 2.2

THE ELEMENTS THAT MAKE UP A MICROCLIMATE

Temperature	winter and summer duration of hot and cold weather
Sun	direction in winter and summer height in summer and winter angle of sunset and sunrise in winter and summer.
Wind	direction of prevailing wind in winter and summer direction of frequent storm winds direction of hurricane winds
Frequency of Storms	what kinds, winter and summer
Rainfall	how much in winter and summer direction of water runoff location of wet and dry spots
Snowfall	how much in winter direction of snow drifts
Humidity	winter and summer
Radiation of Heat from Ground to Sky	at night from buildings, water, and land
Absoption of Heat from Sky to Ground	during day by buildings, water, and land
Topographical Features	mountains, lakes, valleys, plains, woods
Site	rolling, sloping, level, dry, wet
Ground Surfaces	concrete, blacktop, grass, other
Building Surfaces	stone, brick, concrete, wood, aluminum, other
Roof	colour, slope

2.2.1 Vegetated Surfaces

Temperature

Although many vegetated surfaces absorb solar radiation fairly well (albedos of .15 - .25 are typical), the presence of water either at or near the surface means that evapotranspiration occurs readily (in the absence of drought conditions). Evaporation of only 1 gm of water requires roughly 600 calories or 2.4×10^6 Joules per kg of water. This results in cooler temperatures where vegetation is actively transpiring. Tall trees may control temperatures through shading as well (Figure 2.10). At night, temperatures will be cooler where vegetation is low-lying. Trees may act to warm the surface since they absorb and re-emit more infrared energy than does a clear sky. Surface temperature differences of up to 5°C underneath and away from a large tree have been measured. (Figure 2.11).

FIGURE 2.10

HOW SURFACE TREATMENT INFLUENCES TEMPERATURES

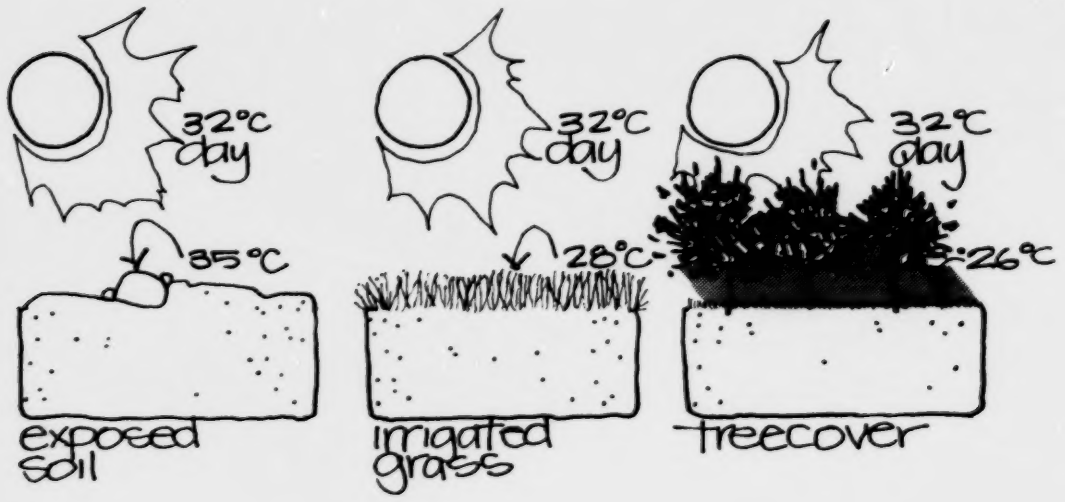


FIGURE 2.11

TEMPERATURE DIFFERENCE
UNDER TREECOVER AT NIGHT

This means that parks or greenspaces with large trees will not cool off as quickly as short grass surfaces.

Humidity

The process of transpiration adds water vapour to the air, therefore increasing the moisture in the atmosphere.

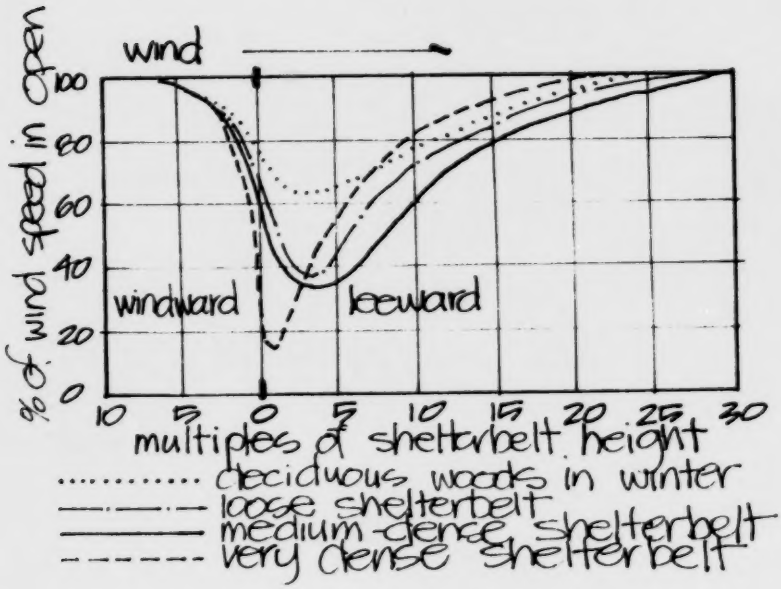
The actual increase is difficult to specify since it depends on wind speed, air temperature and dryness of the air as well as other variables.

Wind Speed

Vegetation is often used to modify wind flow and the extent of this control depends on vegetation size and density. A medium density shelterbelt provides the best overall protection, affecting the wind to some extent a distance of 30 times the height of the object. As Figure 2.12 illustrates, a solid shelterbelt shows the most reduction in windspeed but this recovers fairly rapidly. The optimum windbreak for reducing building energy use will therefore depend on how far it is located from the building.

FIGURE 2.12

THE EFFECT OF A SHELTERBELT AS A FUNCTION OF ITS PENETRABILITY



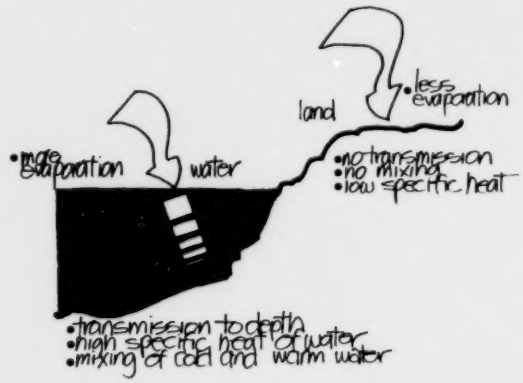
Water Surfaces

Temperature

Water surfaces are generally very conservative in their thermal variations compared to nearby land surfaces. This is despite the fact that water surfaces are among the best absorbers of solar radiation (albedo of 0.03 - 0.10). Figure 2.13 gives a number of reasons why water surfaces are slow to respond to changes in heat and cold. This is especially true as the volume of the water body increases.

FIGURE 2.13

CONTRASTS IN HEATING OF LAND AND WATER



(Strahler, Strahler, 1978)

These factors also cause temperatures over water surfaces to lag behind land temperatures. In Ontario, lakes are colder in spring and summer, and warmer in fall and winter than surrounding land surfaces. If ice forms on the lake surface then this markedly reduces the lake's influence. This temperature lag will then modify surrounding land surfaces depending on the season. The effect

is strongest to the leeward side of a water body or on all sides of the lake when lake to shore breezes occur (Figures 2.14, and 2.15). The effects of onshore winds are felt most within a few kilometres of the shore, but weather records indicate that lake effects may be felt 40 km inland (Eichenlaub, 1979). The distance inland that lake influences are felt is dependent on a variety of factors including the strength of the wind, the nature of the lake-shore (i.e., pavement and buildings or agricultural fields) and topography. For instance over a hot rough urban surface, lake breezes will likely not penetrate further than 0.5 km. (Munn, Hirt and Findlay, 1969).

FIGURE 2.14

VERTICAL CROSS-SECTION OF LAKE BREEZE CIRCULATION

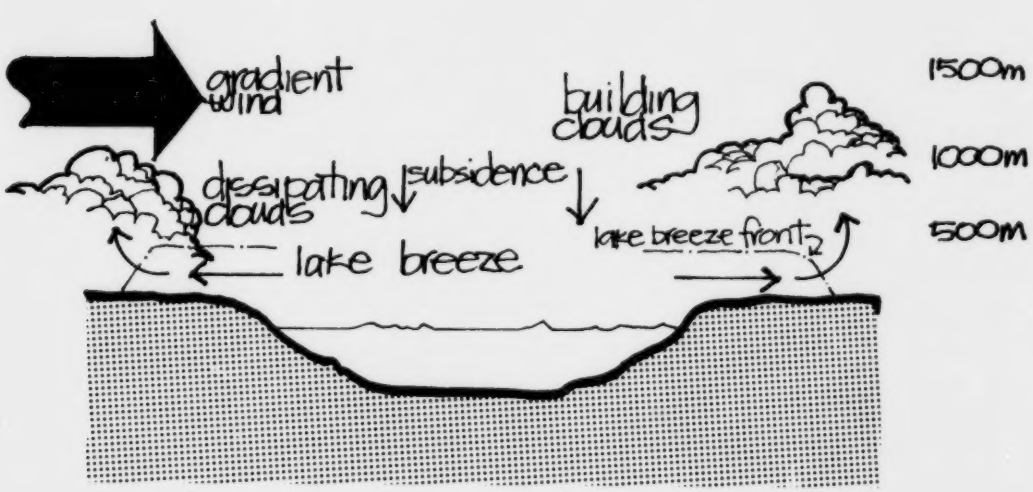
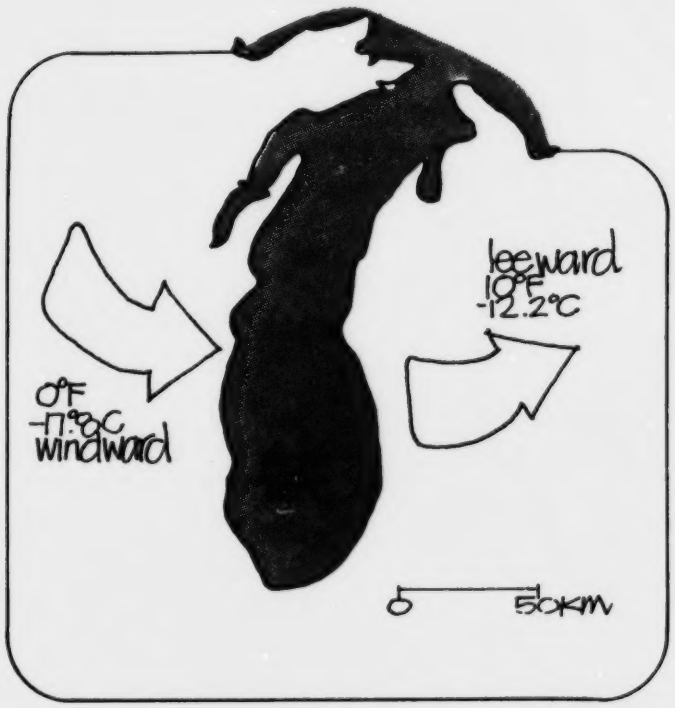


FIGURE 2.15

TEMPERATURE DIFFERENTIALS DUE TO LAKES



Humidity

It is a common misconception that lakes always add water vapour to the atmosphere. Condensation occurs for at least one month throughout the year for all the "Canadian" Great Lakes. In fact, Lake Superior shows an average of 3.5 inches of water condensing onto the lake surface in July. The shallower the lake the less condensation will occur, such as Lake Erie, but for some summer months most of the Great Lakes show very little evaporation. Peak evaporation tends to occur in the fall and winter, when the warm lake water readily evaporates into the atmosphere. Generally smaller lakes will show the same pattern except that the condensation period will be earlier in the spring and the water evaporation rates will be very small due to ice cover.

Wind Speed

Due to lack of surface roughness, winds over lakes are higher than those observed on nearby land surfaces. Furthermore, the wind will be strongest where fetch (the upwind distance of an uninterrupted water surface) is longest. As Figure 2.16 demonstrates, a north-south wind on Lake Michigan has a much longer fetch than for any other Great Lake. Lake Erie and Ontario show the shortest fetches for winds from these directions.

FIGURE 2.16

VARIATION OF FETCH FOR A NORTH-SOUTH WIND FOR THE GREAT LAKES

2.2.3 Landforms

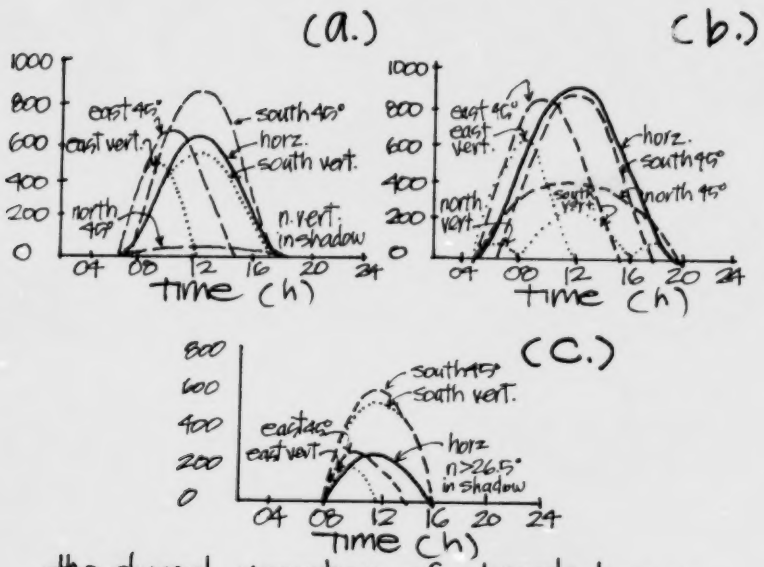
Temperature

Because slopes receive dramatically different amounts of solar energy, they create microclimates that vary widely over short distances. Figure 2.17 displays the intensity with which solar energy arrives on land with different aspects and slopes. Note the small amounts of energy recevied by north slopes and the morning solar radiation maximums for east slopes. South-facing

slopes will always receive more solar radiation in Ontario which means these slopes will be warmer and drier. By contrast, north slopes will generally be cooler and moister. Exact temperature differences will depend on a variety of factors including surface type (i.e., forest, field or pavement), aspect, slope and diurnal pattern of cloudiness (i.e., amount of morning or afternoon cloud). Changes in elevation will also influence the ambient air temperature resulting in a rather predictable decrease in temperature with rise in height (Figure 2.18).

FIGURE 2.17

SOLAR ENERGY RECEIVED
AS A FUNCTION OF SLOPE AND TIME



the diurnal variation of direct-beam solar radiation upon surfaces with different angles of slope and aspect at latitude 40°N for (a.) the equinoxes (21 march, 21 september) (b) summer solstice (22 june) and (c) winter solstice (22 december) (after gates, 1965)

(Oke, 1978)

Another aspect of temperature and topoclimates is the development of cold air drainage under clear skies and light wind conditions. In Ontario these winds are generally very light, flowing in pulses rather than as a steady wind. However, since the coldest air is most dense, it is found at the bottom of depressions, valleys and hollows, leading to large differences in temperature (Figure 2.19).

FIGURE 2.18

TEMPERATURE CHANGE OVER A MOUNTAIN

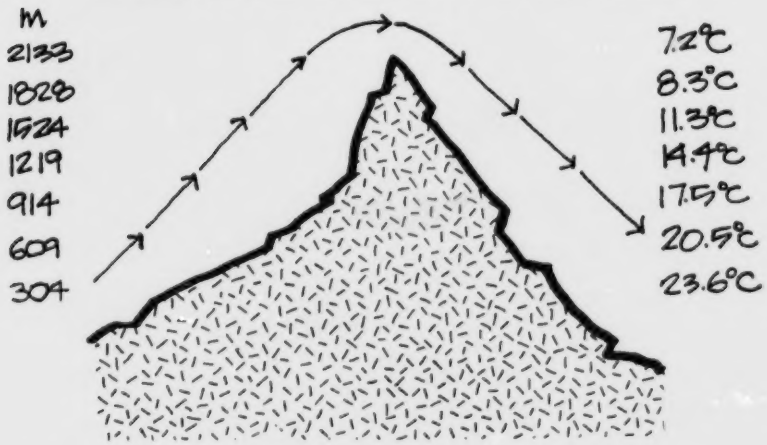


FIGURE 2.19

THERMAL-BELT CHARACTERISTIC IN A VALLEY

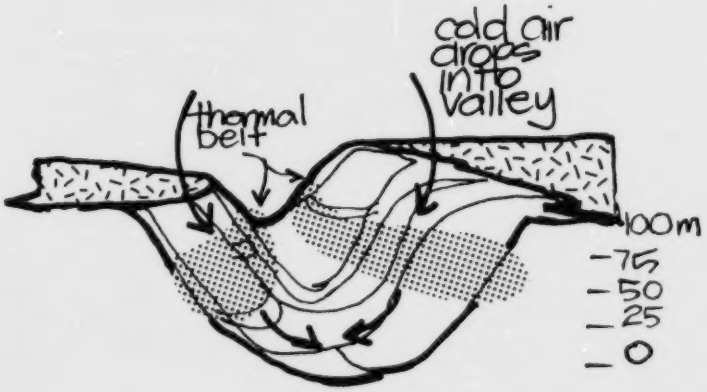


Table 2.3 illustrates the small scale at which cold air drainage can operate. In this case, mean temperature difference of 2.3°C occur over 1.6 m in elevation. To minimize the adverse effect of these temperatures on heating degree days, buildings should be constructed in the "Thermal belt", above the zone of cold air ponding.

TABLE 2.3

NIGHT MINIMUM TEMPERATURES
(0°C) OVER NEARLY LEVEL GROUND

Nights with frost, 1939	Elevation (m) 36.1	36.1	36.3	36.6	37.7
23 - 24 May	-7.6	-6.9	-5.4	-5.1	-3.7
2 - 3 June	-9.4	-7.9	-8.2	-6.7	-5.0
2 - 3 July	-2.1	-1.3	-1.1	0.0	+0.1
11 - 12 July	-2.5	-1.4	0.0	+1.6	+1.9
Mean of 30 coldest nights	-0.6	-0.4	+0.1	+0.7	+1.7

(Geiger, 1965)

Humidity

The topographical control of humidity has not been examined to the same extent as air temperature. In Ontario, south facing slopes will be drier and less humid than north slopes. Nonetheless, the variations in humidity between slopes of different aspect will probably be small except in drought conditions when north slopes still have available soil moisture. In these cases, differences in aspect may become significant.

Windspeed

Topography modifies wind speed and direction in two main ways. Initially, slopes may create winds due to differences in valley heating and cooling under clear sky, light wind situations. Up-valley up-slope (anabatic) winds occur by day and down-valley, down-slope (katabatic) winds by night (Figure 2.20).

FIGURE 2.20

MOUNTAIN AND VALLEY WIND SYSTEMS

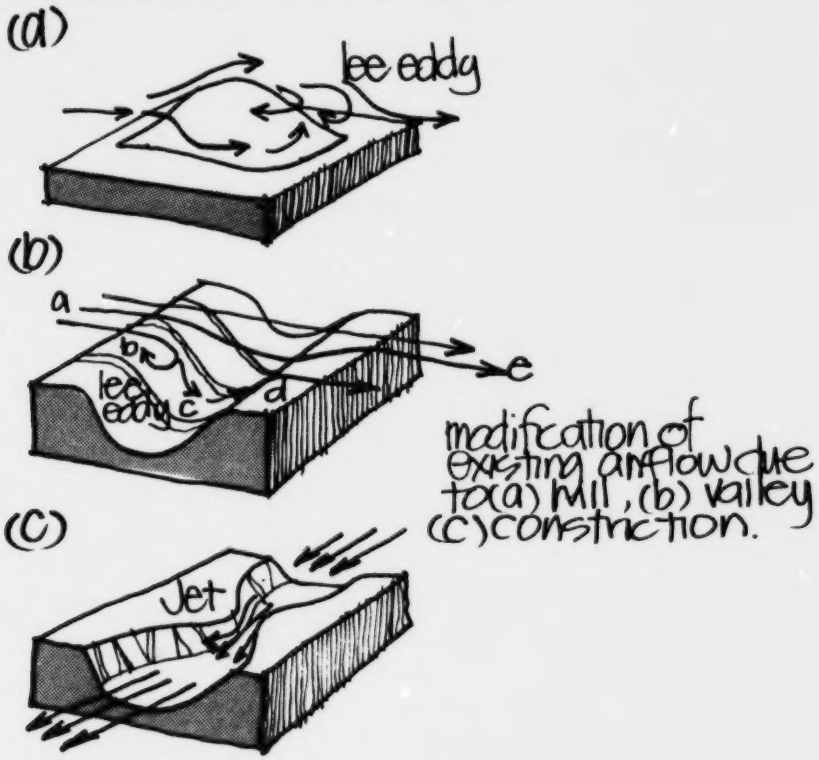
Mountain and valley wind system viewed at a valley cross-section with the reader looking up-valley. (a) By day slope winds are anabatic, and the valley wind fills the valley and moves upstream (into the page away from the reader), with the anti-valley wind coming downstream (out of the page). (b) At night the slope winds are katabatic and reinforce the mountain wind which flows downstream, with the anti-mountain wind flowing in the opposite direction above.

(Oke, 1978)

In Ontario, these winds are light, especially the katabatic flow by night. Aside from generating their own winds, slopes obstruct or modify the regional pattern of air from under stronger winds. Figure 2.21 illustrates the generalized air flow around 3 topographic situations. It should be stressed that these patterns are generalized and may be far more complex. In (a) air accelerates on top of and around the hill, slowing down in the lee eddy. In (b) air slows down at point C compared to the initial airflow at point A. Diagram (c) is self explanatory.

FIGURE 2.21

MODIFICATIONS TO EXISTING AIRFLOW



2.2.4 Urban Surfaces

The change in the natural environment of fields, trees and streams to a built-up environment of buildings and roads has a dramatic impact on local and regional (depending on size of urban area) climate. The consequences of urbanization as reflected in climatic changes is presented in Table 2.4 while further explanations of temperature, wind and humidity follows.

TABLE 2.4

AVERAGE CHANGES IN CLIMATIC ELEMENTS CAUSED BY URBANIZATION

Element	Compared to Rural Environment
Contaminants:	
condensation nuclei and particulates;	10 times more
gaseous admixtures	5 to 25 times more
Cloudiness:	
cover;	5 to 10% more
fog, winter;	100% more
fog, summer	30% more
Precipitation:	
totals;	5 to 10% more
days with less than 5 mm;	10% more
snowfall	5% less
Relative Humidity:	
winter;	2% less
summer	8% less
Radiation:	
global;	15 to 20% less
ultra-violet, winter;	30% less
ultra-violet, summer;	5% less
sunshine duration	5 to 15% less
Temperature:	
annual mean;	0.5 to 1.0°C more
winter minima (average);	1 to 2°C more
heating degree days	10% less
Wind speed:	
annual mean;	20 to 30% less
extreme gusts;	10 to 20% less
calms	5 to 20% more

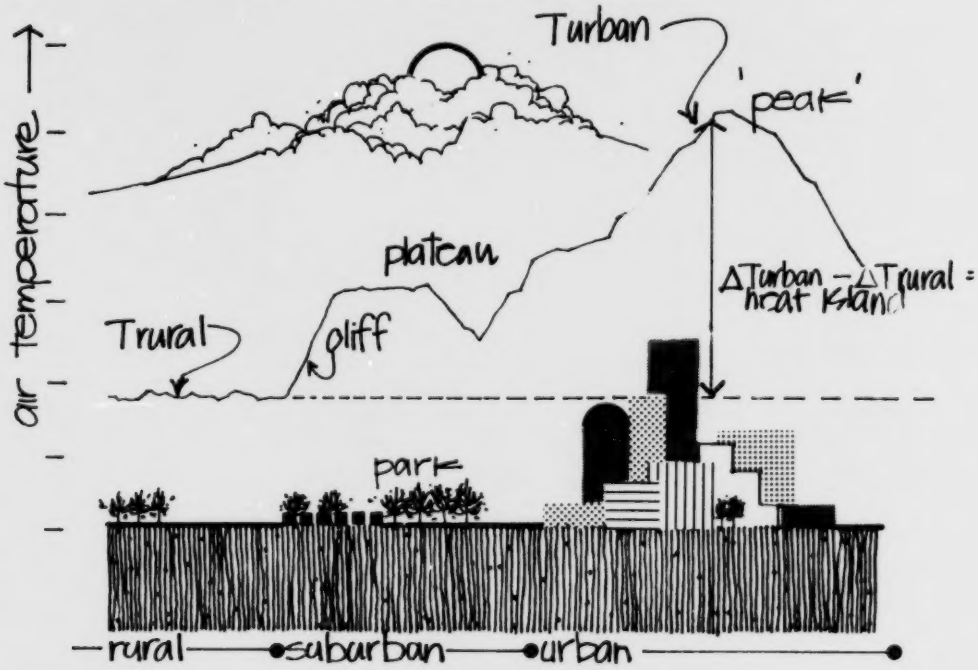
Source: "Climate and Urban Planning" by H.E. Landsberg, W.M.O. Technical note No. 108, pp 372.

Temperature

Urban areas have a marked influence on air temperature (urban heat island) especially under conditions of clear skies and light winds. Figure 2.22 illustrates the typical form of this temperature increase including a suburban cliff and central peak in air temperatures.

FIGURE 2.22

GENERALIZED CROSS-SECTION OF
A TYPICAL URBAN HEAT ISLAND

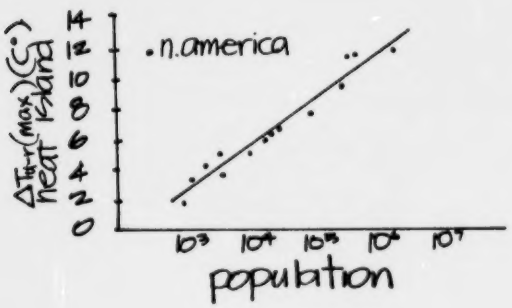


(Oke, 1978).

This effect is greatest (up to 10-12°C) for large urban centres (i.e., Toronto, Montreal), but is evident in small settlements as well. (Figure 2.23) Although the heat island is likely due to a variety of factors, there is a strong relationship between building size and street width (equation 1).

FIGURE 2.23

RELATIONSHIP BETWEEN POPULATION AND HEAT ISLAND INTENSITY



(Oke, 1978)

Maximum Heat Island = $7.54 + 3.97 \ln \left(\frac{\text{Building Height}}{\text{Street Width}}\right)$

under clear, calm conditions with no anthropogenic (man-made) heat release. (Oke, 1980).

Equation 1 allows maximum heat island intensities to be quickly calculated for clear, calm conditions in summer (i.e., antropogenic heat release is small).

Humidity

As in other situations, our understanding of the spatial and temporal pattern of humidity lags behind that of temperature. For urban surfaces this is no different. However, there is evidence to suggest that urban air is usually drier by day and moister at night for typical summertime situations. When artificial (man made) sources of moisture are large, the city may be moister throughout the day as well. This is most likely to be the case in winter when rural evapotranspiration rates are small and man-made sources due to combustion (particularly space heating) have increased. In either case, the absolute differences between rural and urban areas are generally small.

Wind Speed and Direction

The city produces its own wind under certain situations. This urban/rural wind is most likely to occur when regional winds are light and skies are clear. In this case, the urban heat island develops and induces atmospheric pressure differences which result in light winds flowing from the rural areas to the urban core (Figure 2.24). These urban winds are generally light.

The urban area alsc modifies air flow, rather like the topographic case, since air must now flow around and between man-made obstructions. This generally results in a reduced urban wind speed. The general pattern disguises a very complex air flow which in fact may be slower overall, but produces a much faster flow in certain areas.

FIGURE 2.24

URBAN AIR CIRCULATION IN CALM CONDITIONS

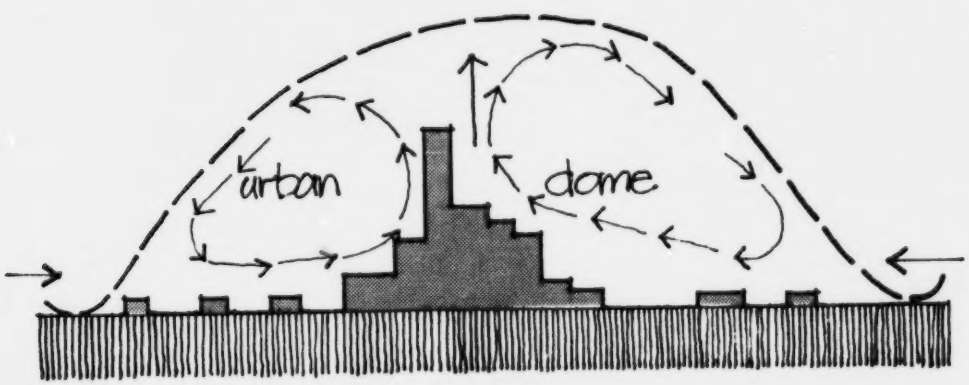
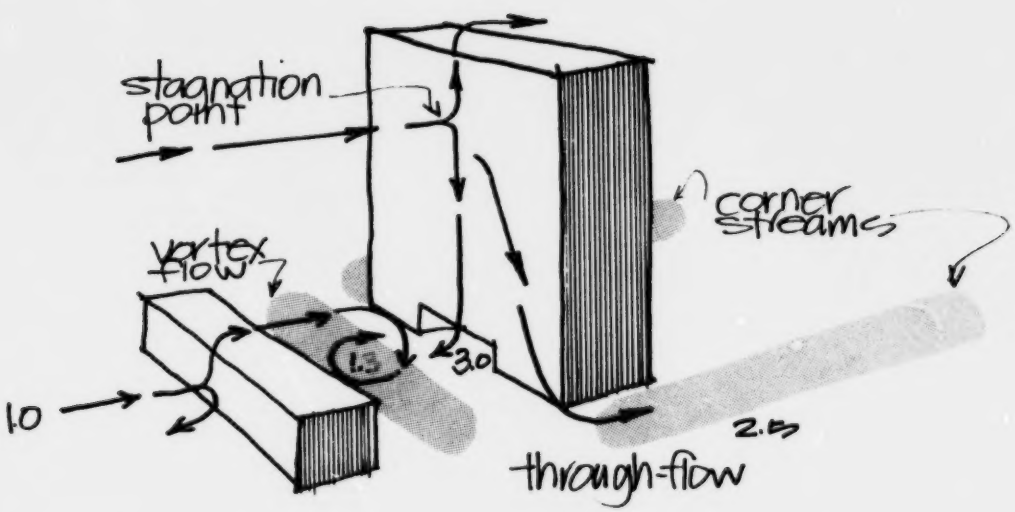


Figure 2.25 illustrates the flow around a low and a high building in combination.

FIGURE 2.25

URBAN WIND CONDITIONS



Airflow in the vicinity of a tall building with smaller buildings upwind. The stippled areas delineate areas of substantially increased wind speed at pedestrial level.

(T. Oke, 1977).

2.3 Air Pollution

While accurate statistical data is weak for general conditions, it is accepted that climatic conditions play a central role in determining the level of pollution in urban and rural areas. Topography will alter climatic conditions locally and can encourage either dispersal or concentration of pollutants. While strong winds will clear the air, calms or very light winds will allow pollutants to settle.

The relationship between climate and air pollution is an extremely complex one in which there is both action and reaction. It is difficult in an urban context to separate the influence of air pollution on the climate from that of the urban development (which caused the pollution in the first place). While nearly all pollutants exist naturally in the atmosphere, the concentration over cities are, on the average, sixteen times greater than over inland rural areas and 160 times greater than over the oceans. (Landsberg, 1938).

Ontario's Climate

3.0 ONTARIO'S CLIMATE

3.1 Introduction

The Province of Ontario extends from the shores of Hudson Bay to the Great Lakes, spanning a distance of 1,600 kilometres between latitudes 42°N and 56°N. This vast area encompasses a variety of different climates. In general, Ontario has warm summers and mild winters in the southern part of the province with cooler annual conditions as one travels north. Due to the large variation in climate within the province, the Atmospheric Environment Service of Environment Canada has dealt with Ontario's climate in two parts:

- The Climate of Southern Ontario, Climatological Study No. 5
- The Climate of Northern Ontario, Climatological Study No. 6

The approximate dividing line between southern and northern Ontario for the purposes of these reports is 46°N Latitude. This report will address Ontario's climate in a similar manner as the reader will likely reference the government publications in the course of his work. A majority of the material presented in this chapter has been drawn from these two reports.

3.2 Climatic Regions

The Province has been divided into climatic regions which, in most cases, represent areas with similar general climatic conditions. The regions also provide a framework for summarizing the climate characteristics generally referred to. The climatic regions of southern and northern Ontario are shown on Figures 3.1 and 3.2 respectively. Where appropriate reference will be made to these climatic regions in this chapter.

It should be noted that there are very few weather records for the area of northern Ontario north of the Canadian National Railway which runs across the province near the 50°N Latitude.

The climatological information published by the government has been collected from numerous stations throughout Ontario. While this chapter will touch upon general climatic conditions for the province and present means for each region it is recommended that the records of the closest climatological station be utilized for more accurate information. Recording stations in southern and northern Ontario are identified on Figures 3.3 and 3.4 respectively. As the information for Northern Ontario was published in 1968, additional stations may have opened.

FIGURE 3.1

CLIMATIC REGIONS OF SOUTHERN ONTARIO

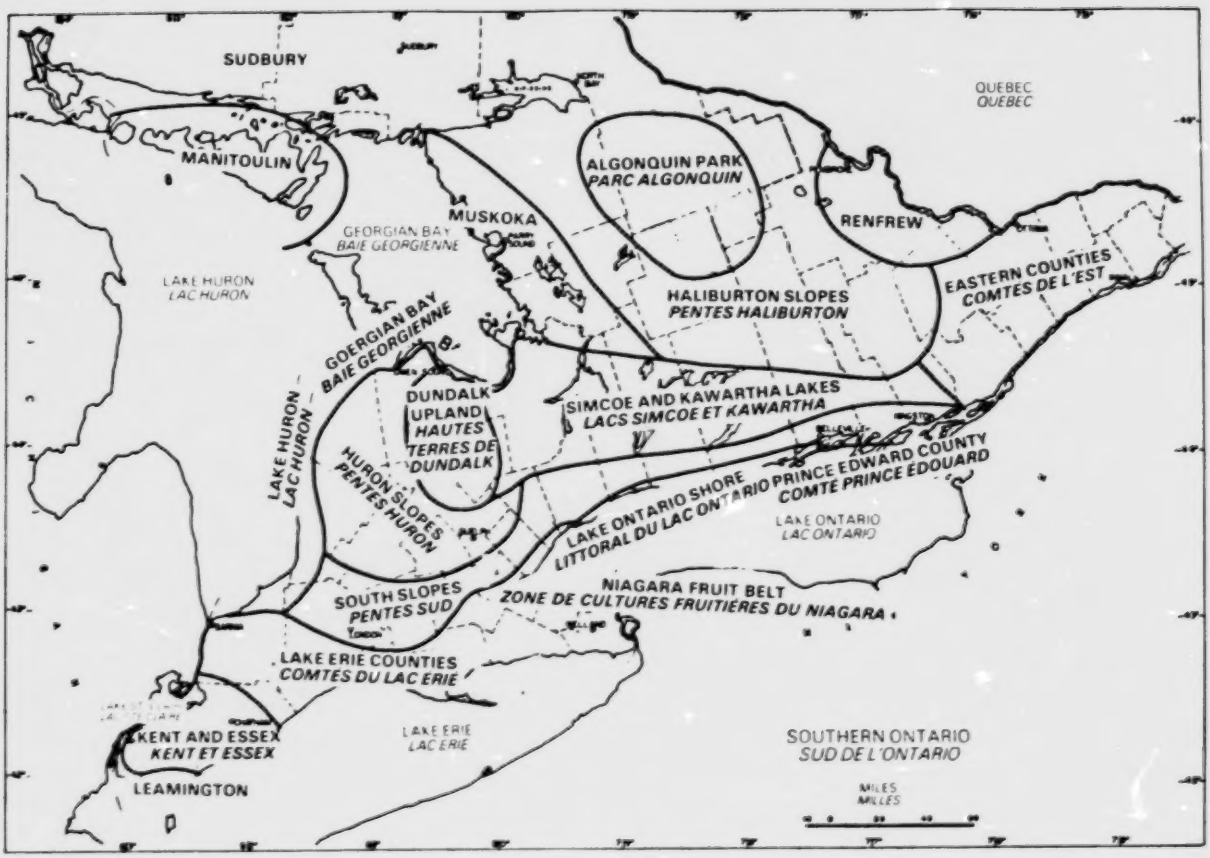


FIGURE 3.2

CLIMATIC REGIONS OF NORTHERN ONTARIO

The area has been divided into nine climatic regions on the basis of temperature and precipitation. Representative climatic data from each region are listed in Table 3.3.

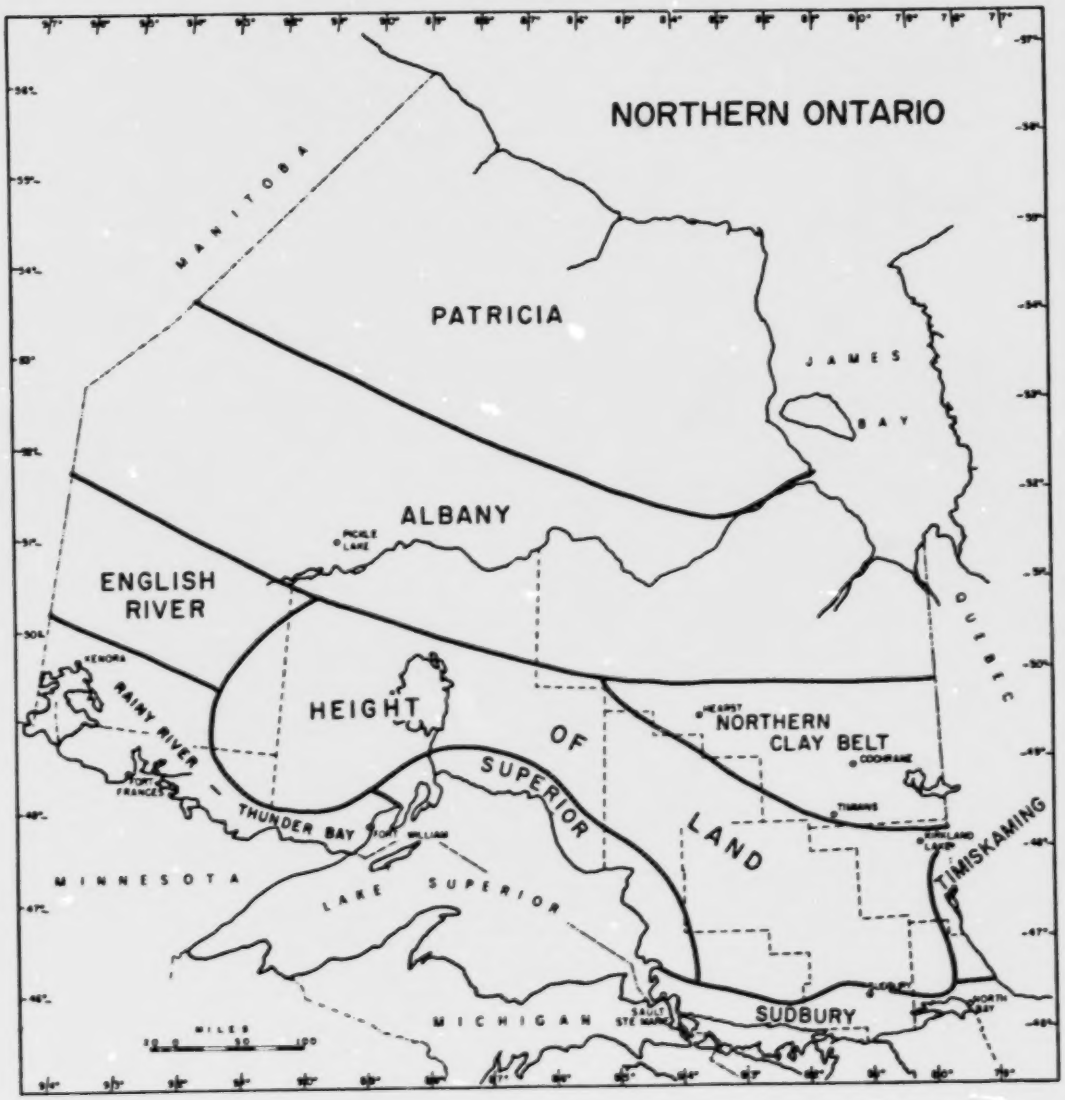


FIGURE 3 3

CLIMATOLOGICAL STATIONS IN SOUTHERN ONTARIO

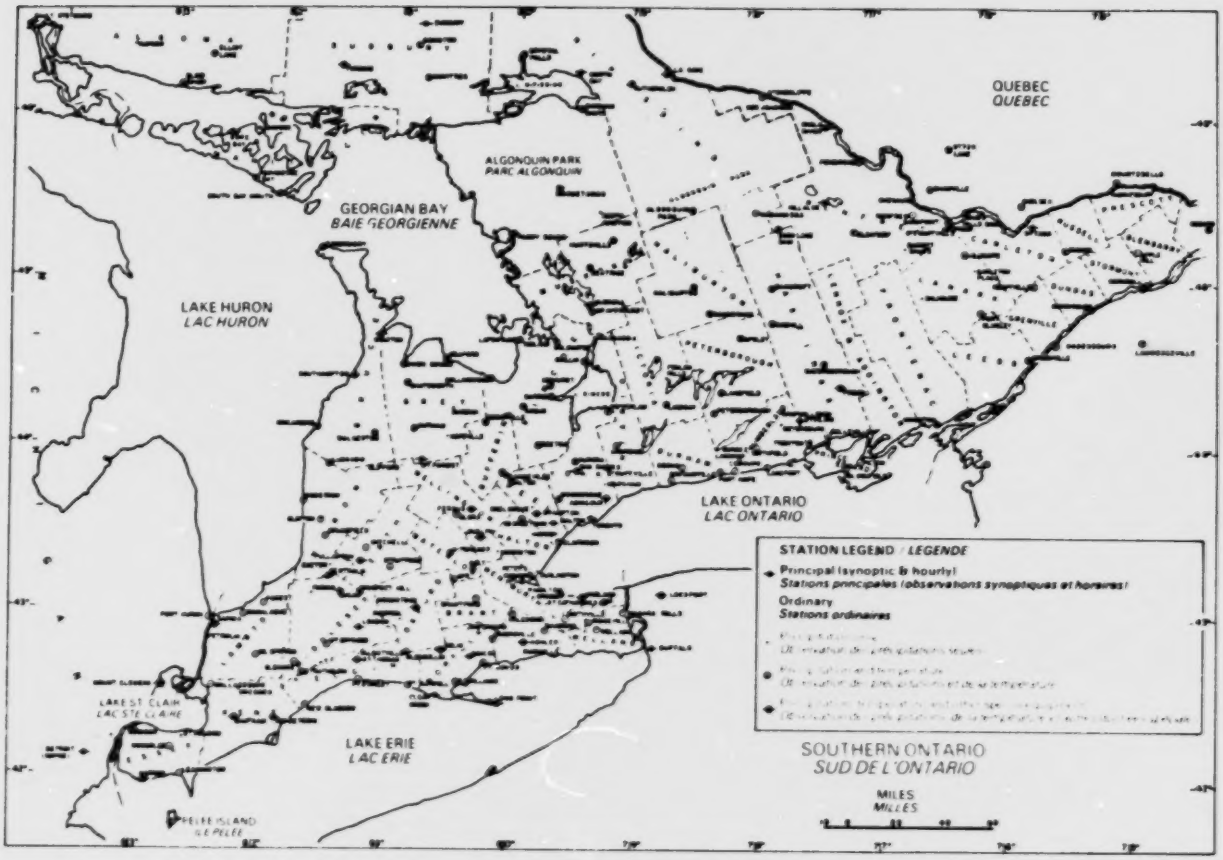


FIGURE 3.4

CLIMATOLOGICAL STATIONS IN NORTHERN ONTARIO

There is a sparse but fairly uniform distribution of climatological stations south of the 50°N latitude. North of this line, however, in the largely uninhabited portions, there are fewer than a dozen climatological reporting stations.

3.3 Climatic Controls

To adequately discuss how planners can utilize climatic information for energy conservation, an understanding of the controls on the climate of Ontario is important. The climate of a particular area is the result of past weather experiences that combine to form the predicable climatic conditions for that area. These conditions are created by a combination of temperature, moisture and sunlight which is repeated annually and in subject to local variation as discussed in section 2.2.

The climate of Ontario is largely controlled by four factors:

- solar radiation (sunlight)
- weather systems
- physiography
- the Great Lakes

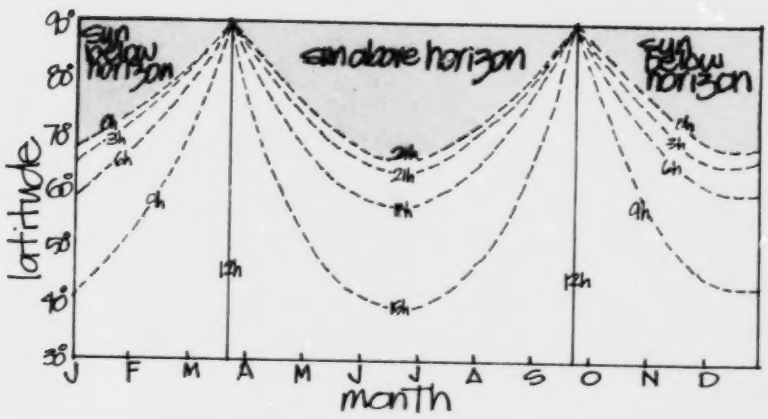
3.3.1 Solar Radiation

Since the sun is the source of almost all the energy or heat received by the earth's surface, its variability creates different climates. Figure 3.5 shows the important effect latitude has on the duration of daylight. The influence of this on air temperature is shown for two Ontario locations in Table 3.1.

Once solar radiation is absorbed by the earth's surface it is converted to heat and this heat is transferred to the lower atmosphere. This heat can then be transported from one area to another by winds. This is an important aspect of the climate of Southern Ontario that will be discussed under weather systems.

FIGURE 3.5

DURATION OF DAYLIGHT AS
A FUNCTION OF LATITUDES



(Hare & Thomas, 1974)

TABLE 3.1

COMPARISON OF MEAN DAILY TEMPERATURE
AND HOURS OF DAYLIGHT FOR A
NORTHERN AND SOUTHERN ONTARIO LOCATION

	January	April	July	October
Armstrong, Ontario 50°17'N, 88°54'W				
Mean Daily Temperature (°C)	-20.7	-0.5	16.4	3.6
Hours of Daylight	8.0	12.2	16.3	12.2
Windsor, Ontario 42°16'N, 82°58'W				
Mean Daily Temperature (°C)	-4.3	8.2	22.3	11.6
Hours of Daylight	9.0	12.2	15.3	12.1

(Phillips, McCulloch, 1971 & Hare, Thomas, 1974)

Figure 3.5 illustrates how latitude controls the maximum amount of sunlight available to heat the earth's surface. However, the actual amount received is constantly changing due to variations in cloud cover and atmospheric turbidity (i.e. atmosphere's dirtiness). Generally, cloud influences are considerable, however, locally, air pollution may be important, for instance, solar radiation measurements indicate that Scarborough receives 15-20% more solar radiation than does Toronto due to its less polluted atomosphere.

As well, local variations in solar radiation due to slope and aspect create distinct microclimates. For instance, south slopes are generally warmer and drier than north slopes since they receive more energy from the sun.

3.3.2 Weather Systems

Air Masses

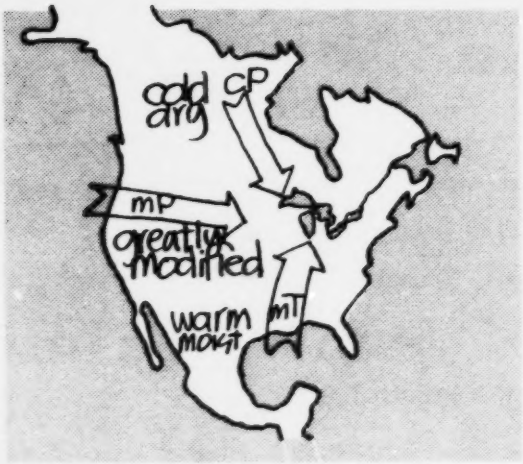
A prominant aspect of the weather in Ontario is that it is variable in all seasons. Warm, humid weather one day may be replaced by cool, dry weather the next. The temperature and humidity characteristics of the daily weather depend very much on the type of air masses that are affecting Ontario at the time. Figure 3.6 illustrates the main air masses that influence Ontario. From a building energy use standpoint, if a cold arctic air mass covers Ontario, space heating requirements increase because outside temperatures are colder. Alternately, when hot, humid air from the Gulf of Mexico (mT), invades Ontario, building energy use increases due to air-conditioning requirements. The planner cannot control the movement of these air masses, but by utilizing various microclimatic principles discussed elsewhere in this report, their impact on building energy use can be lessened.

As already implied, these air masses carry with them the characteristics of the areas from which they originate. Because of the size of Ontario, regional differences occur in the frequency

of occurrence of various air mass types. For instance, hot, humid air from the Gulf of Mexico occurs quite often in Southern Ontario (up to 40% of the time in summer), but is rare north of Lake Superior (less than 10% of the time). In winter, cold polar air dominates Northern Ontario while Southern Ontario may receive tropical air from the Gulf of Mexico causing a "January thaw" (Phillips, McCulloch, 1972).

FIGURE 3.6

MAIN AIR MASS SOURCE REGIONS AFFECTING ONTARIO

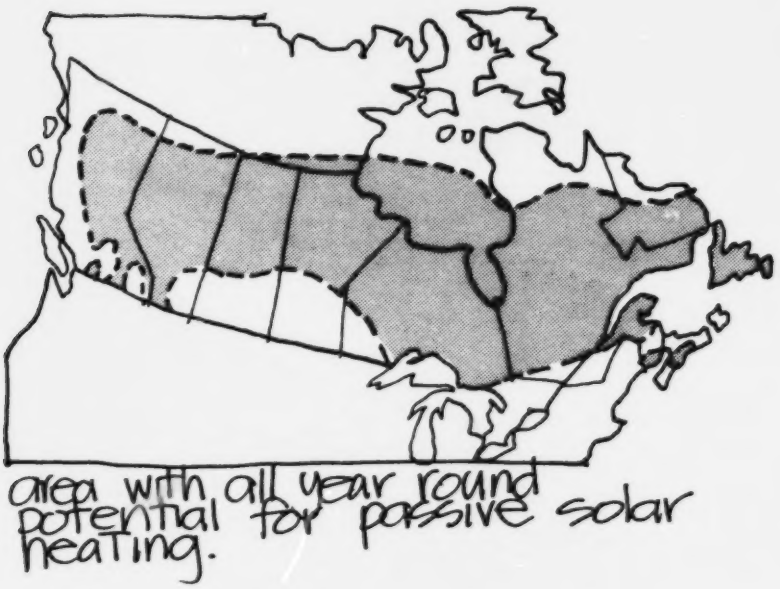


(Eichenlaub, 1979)

The implication of this for planners is that land use control to reduce building energy consumption will vary between Northern and Southern Ontario. Although both areas require techniques to reduce building heating needs in winter, Southern Ontario also needs to reduce warm summer temperatures that give rise to the need for air conditioning. Some areas of Northern Ontario require building heating in all months of the year (Figure 3.7). Comments in subsequent sections will distinguish between these two areas of Ontario.

FIGURE 3.7

AREAS WITH YEAR ROUND HEATING REQUIREMENTS



(Architects Manual, 1981)

Cyclonic Storms

Storms (or cyclones) form along the boundaries of these air masses under certain conditions. Figures 3.8 and 3.9 illustrate the typical path of these disturbances through Ontario. Strong winds, cloud and precipitation are associated with cyclones although they are more usually intense in winter. In the summer the main storm tracks move north so that Northern Ontario experiences cloudier skies at this time of the year. However, in winter the prime storm tracks move south, creating cloudier conditions in Southern Ontario.

FIGURE 3.8

GENERALIZED WINTER STORM TRACK

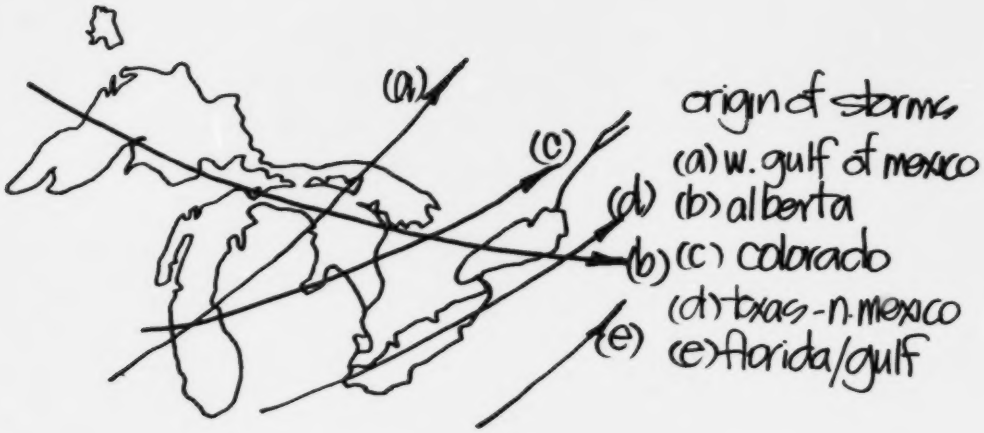
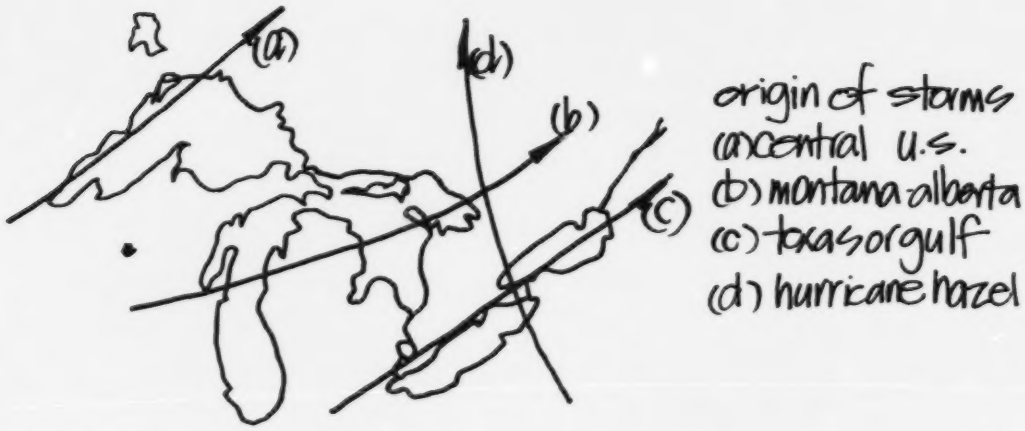


FIGURE 3.9

GENERALIZED SPRING AND AUTUMN STORM TRACK



This variation in cloud cover due to changes in the main storm track, controls the amount of solar radiation available at the surface. Northern Ontario records more bright sunshine in winter than Southern Ontario, despite the fact that the sun shines for fewer hours each day (Figure 3.1). In summer Southern Ontario records greater amounts of bright sunshine (due to the shift north in the storm track) despite the fact that Northern Ontario receives more daylight hours (Table 3.1). As well, the year to year variation in climate that occurs in Ontario is related to a large extent to the variation in nature and frequency of the cyclonic storms that cross the area.

3.3.3 Physiography

As discussed in chapter 2, landform can have a significant influence on local climate. The topography of Ontario is fairly regular, rising from the Great Lakes (180 m elevation) to highest land (about 460 - 490 m) in the Dundalk Uplands, Algonquin Park and north of Lake Superior. In general the land rises gently and thus only local conditions will create mesoclimates that differ from the regional norms.

A major exception that should be noted is the Niagara Escarpment which influences the climate of those regions in which it is located.

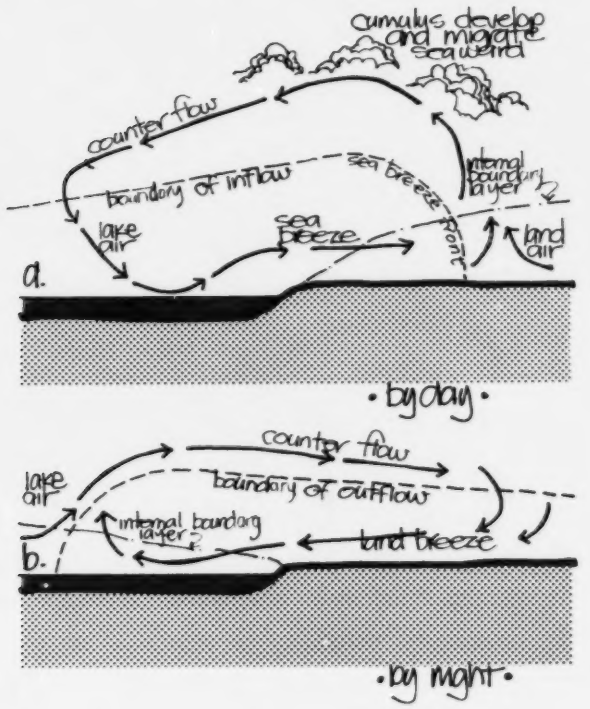
3.3.4 The Great Lakes

The final major control on the climate of Ontario is the Great Lakes. Because of their vast size (95 000 square miles), they not only are an abundant source of moisture but also may remove or add great quantities of heat with the overlying atmosphere. Because water bodies are able to store heat so effectively, they remain warm well into the fall and early winter. Air traversing the lakes at this time year is warmed, causing clouds to form and snowstorms down wind of the lakes. Figure 3.10 shows this lake

influence which caused reductions in sunshine of 1-2 hours/day for lee of lake stations. The reverse occurs in spring and summer when the lakes remain much colder than the surrounding land surfaces. This suppresses cloud development and stations downwind from the lakes show ½ to 1½ hours more sunshine/day. The Great Lakes also may create their own wind systems under clear skies and light regional winds. Cool lake breezes occur by day, moving up to 40 km inland (Eichenlaub, 1979). Thus, temperatures are moderated along the lake shore, especially to the lee of the lakes since areas are influenced by local lake breeze circulations as well as prevailing winds. In these locations, winter temperatures will be warmer (until ice forms) and summer temperatures will be cooler.

FIGURE 3.10

LAND AND LAKE BREEZE CIRCULATIONS ACROSS A SHORE LINE



3.3.5 Summary of Climatic Controls

These climatic influences affect patterns of temperature, heating degree days, solar radiation or bright sunshine and winds occur. These are the climatic variables of most interest to the energy conscious planner. The influence of latitude and the Great Lakes show the largest control, the latter especially around Lake Superior. Heating degree days are accumulated throughout the year whenever mean daily temperatures fall below 18°C. Thus, twice as much fuel will be needed for buildings at Pickle Lake (51°N - 7000 heating degree days) as in Windsor (42°N - 3500 heating degree days) if their construction is similar. The influence of the Great Lakes on solar radition and the pattern of sunshine hours is significant, especially to the lee of the lakes.

In January, the path of cyclonic storms controls prevailing wind directions, giving mostly SW winds in Southern Ontario. In Northern Ontario, NW winds seems to predominate due to outbreaks of cold polar air which come from that direction. In summer, winds are more variable and defined patterns aren't easily discernable.

3.4 Regional Climatic Conditions

The mean climatic conditions for each of the climatic regions in Southern and Northern Ontario are presented in Table 3.2 and 3.3 respectively. Wind speed and direction are determined by the nature of the air masses that cross Ontario. The mean frequencies and mean speeds for four locations in Ontario are given in Table 3.4. The mean monthly mixing ratio, an indication of humidity is also given for these four locations in Table 3.5. This information is provided as an indication of what is available. It is recommended that reference be made to the nearest climatological station when accurate data is required.

TABLE 3.2

REGIONAL CLIMATES OF SOUTHERN ONTARIO

Climatic Region	Stormont	Niagara Fruit Belt	Kent and Essex	Lake Erie Counties	Lake Ontario Shore	Prince Edward County	Lake Huron Georgian Bay	South Slopes	Huron Slopes	Simcoe and Kawartha Lakes	Eastern Counties	Muskoka	Madawaska	Nipissing	Dundalk Upland	Haliburton Slopes	Algonquin Park	Southern
Altitude (feet above sea level)	600	300	600	700	300	300	700	700	1100	700	400	700	800	600	1600	1200	1500	800
Mean Annual Temperature °F	49	48	48	47	45	45	45	45	44	43	43	42	42	41	42	41	40	41
Mean Daily Maximum Temperature °F																		
– January	32	32	31	31	29	29	29	28	28	26	24	25	24	22	24	23	22	21
– April	55	52	55	53	51	50	50	52	51	51	52	47	49	51	48	50	48	48
– July	81	81	82	81	79	79	78	81	79	79	81	76	78	80	77	78	77	77
– October	62	60	61	61	58	58	58	59	58	58	57	55	56	56	56	55	54	54
Mean Daily Minimum Temperature °F																		
– January	20	20	19	17	13	13	17	13	14	8	5	9	6	3	9	2	0	0
– April	37	36	36	35	34	35	33	33	32	31	33	30	29	30	30	29	26	27
– July	64	62	62	59	59	60	58	58	56	57	57	56	55	56	54	54	53	55
– October	45	42	43	41	40	40	42	39	39	37	37	40	38	36	36	35	33	35
Daily Range of Temperature °F																		
– January	11	12	12	13	16	15	12	15	14	18	19	16	18	19	15	21	22	21
– July	17	19	20	21	20	19	20	23	22	23	24	20	23	24	23	24	27	24
Extreme Low Temperature °F	-20	-16	-27	-34	-30	-33	-35	-39	-43	-42	-40	-41	-48	-40	-27*	-50	-50	-55
Extreme High Temperature °F	105	104	106	106	104	100	102	105	102	104	104	100	98	103	93*	103	103	106
Mean Date of Last Frost in Spring	May 1	May 5	May 5	May 12	May 12	May 12	May 15	May 15	May 20	May 18	May 15	May 25	May 25	May 18	May 31	May 25	May 31	May 31
Mean Date of First Frost in Fall	Oct 20	Oct 15	Oct 15	Oct 10	Oct 8	Oct 10	Oct 10	Oct 5	Sept 30	Sept 28	Sept 28	Sept 28	Sept 25	Sept 25	Sept 20	Sept 17	Sept 10	Sept 20
Mean Annual Frost Free Period (Days)	170	165	165	150	150	150	150	145	135	135	135	125	125	130	115	115	100	110
Start of Growing Season	Apr 6	Apr 10	Apr 8	Apr 10	Apr 12	Apr 12	Apr 15	Apr 13	Apr 17	Apr 18	Apr 15	Apr 23	Apr 22	Apr 18	Apr 20	Apr 22	Apr 25	Apr 23
End of Growing Season	Nov 12	Nov 10	Nov 11	Nov 8	Nov 3	Nov 5	Nov 5	Nov 3	Oct 31	Oct 28	Oct 28	Oct 28	Oct 27	Oct 27	Oct 25	Oct 24	Oct 21	Oct 22
Mean Annual Length of Growing Season	220	215	215	210	205	205	205	205	195	195	195	190	190	190	190	185	180	180
Mean Annual Growing Degree Days	4200	3900	4100	3700	3500	3500	3400	3500	3200	3200	3400	3000	3000	3100	2800	2900	2700	2900
Mean Annual Precipitation (inches)	30	31	30	34	34	33	33	30-38	32-39	32	30-37	33	39	28	27	28-40	27-37	33
Mean Annual Snowfall (inches)	35	45	40	50	65	60	100	70	110	70	80	90	110	75	100	80	80	80
Mean Annual Potential Evapotranspiration (inches)	26	25	26	25	24	24	24	24	23	23	24	22	23	23	22	22	21	22
Mean Annual Actual Evapotranspiration (inches)	22	21	21	22	21	21	22	22	22	22	22	20	21	21	21	21	20	21
Mean Annual Moisture Deficiency (inches)	4	4	5	3	3	3	3	2	1	1	2	2	2	3	1	2	1	1
Mean Annual Water Surplus (inches)	9	10	10	13	13	13	13	12	16	12	13	14	16	11	16	14	12	13

NOTE: Most data in this table are based on 30 to 50 years of record; however those indicated with an * began in 1944.

TABLE 3.3

REGIONAL CLIMATES OF NORTHERN ONTARIO

Climatic Regions	Sudbury North Bay Sault Ste. Marie	Rainy River Thunder Bay	Timiskaming	Superior	Northern Clay Belt	English River	Height of Land	Albany	Patricia
Altitude (feet above sea level)	600 - 1000	600 - 1400	600 - 1000	600 - 1400	700 - 1000	1000 - 1500	1000 - 1600	0 - 1500	0 - 1500
Mean Annual Temperature (°F)	40	36	36	35	34	34	34	30	25
Mean Annual Minimum Temperature (°F)	-30	-40	-35	-35	-40	-40	-45	-42	-45
Daily Range of Temperature –July	23	23	23	19	24	22	26	20	19
Mean Daily Maximum Temperature (°F)									
–January	22	14	18	18	11	7	14	4	0
–April	48	48	46	42	43	44	44	40	33
–July	77	78	77	72	75	77	76	73	69
–October	54	52	52	50	49	49	50	45	40
Mean Daily Minimum Temperature (°F)									
–January	2	-8	-8	-4	-12	-12	-12	-16	-20
–April	28	25	24	24	22	22	22	17	10
–July	54	54	53	50	51	55	50	51	47
–October	36	32	33	34	32	32	30	30	28
Mean Date of Last Frost in Spring	May 31	May 31	June 10	June 5	June 8	May 30	June 15	June 12	June 18
Mean Date of First Frost in Fall	Sept. 20	Sept. 12	Sept. 13	Sept. 15	Sept. 7	Sept. 15	Sept. 2	Sept. 5	Aug. 31
Mean Annual Frost Free Period (days)	112	104	96	103	92	108	80	86	75
Start of Growing Season	Apr. 25	Apr. 26	Apr. 27	May 6	May 7	May 3	May 5	May 15	May 24
End of Growing Season	Oct. 24	Oct. 17	Oct. 15	Oct. 15	Oct. 13	Oct. 13	Oct. 13	Oct. 8	Oct. 1
Mean Annual Length of Growing Season	183	175	172	163	160	164	162	154	131
Mean Annual Growing Degree –days	2800	2600	2600	2000	2200	2300	2200	1800	1400
Mean Annual Freezing Degree –days	2000	3500	2700	3000	3800	4200	3800	5000	6000
Mean Annual Precipitation (inches)	33	26	32	34	31	25	30	26	24
Mean May to September Precipitation (inches)	16	15	16	16	16	15	15	15	14
Mean Annual Snowfall (inches)	85	75	85	110	110	80	95	95	80
Mean Annual Potential Evapotranspiration (inches)	22	21	21	20	20	21	19	18	16
Mean Annual Actual Evapotranspiration (inches)	21	21	21	20	20	20	19	18	16
Mean Annual Moisture Deficiency (inches)	1	0	0	0	0	1	0	0	0
Mean Annual Water Surplus (inches)	13	5	12	14	13	5	11	9	7

TABLE 3.4

MEAN DAILY WIND SPEED AND DIRECTION

Direction	January		April		July		October	
	F	S	F	S	F	S	F	S
OTTAWA (1939-1966)								
N	6	7,8	9	8,8	7	7,5	8	8,0
NE	9	9,4	8	9,1	6	6,6	8	8,7
E	17	11,7	17	12,8	8	7,6	14	9,4
SE	4	8,1	5	9,3	5	7,3	5	7,6
S	8	9,3	10	10,1	13	8,4	13	9,3
SW	13	12,6	13	11,5	23	9,7	20	11,4
W	22	10,5	18	11,1	20	9,1	15	9,6
NW	19	11,7	19	11,8	16	9,6	15	11,1
CALM	2		1		2		2	
	Maximum Hourly Speed SW 48 – January 1950							
	Maximum Gust 84 – May 1959							
TORONTO (1937-1966)								
N	11	9,9	10	11,1	7	6,8	10	8,3
NE	12	12,0	15	13,3	10	8,3	12	9,2
E	9	15,4	17	12,3	14	7,7	14	9,5
SE	3	13,2	4	9,4	7	7,3	5	8,3
S	5	13,2	8	11,4	13	9,2	9	9,6
SW	21	17,7	13	12,3	18	8,7	18	11,4
W	22	15,8	14	13,0	13	7,4	14	10,1
NW	17	12,8	19	12,9	17	9,6	17	10,6
CALM	•		•		1		1	
	Maximum Hourly Speed SW 56 – March 1942							
	Gusts Not Recorded							
WINDSOR (1941-1966)								
N	8	12,2	10	13,2	10	8,8	10	9,9
NE	10	12,0	15	12,2	14	8,5	9	9,9
E	6	11,1	11	11,6	7	6,3	7	7,6
SE	5	8,7	8	9,8	6	6,5	6	7,2
S	12	10,6	13	11,9	14	8,1	17	9,3
SW	25	13,5	16	13,3	20	8,8	21	9,9
W	18	14,1	15	14,8	13	9,1	14	10,7
NW	12	15,2	8	15,2	6	9,6	10	11,7
CALM	4		4		10		6	
	Maximum Hourly Speed SW 57 – March 1951							
	Maximum Gust 92 – March 1959							
NORTH BAY (1939-1966)								
N	18	12,2	20	12,8	14	10,1	15	11,6
NE	10	11,3	12	12,3	7	9,6	9	11,7
E	16	11,3	13	12,3	6	7,6	9	9,8
SE	10	7,8	7	9,6	7	6,4	11	8,1
S	11	9,3	9	8,9	11	7,5	14	8,9
SW	12	10,7	19	10,9	31	9,9	20	10,8
W	13	10,8	10	10,4	13	9,6	12	10,5
NW	9	10,4	9	11,9	9	10,0	9	11,1
CALM	1		1		2		1	
	Maximum Hourly Speed NE 48 – March 1956							

• Less than 0.5 per cent

LEGEND F Direction frequency in per cent S Speed in p.h.

TABLE 3.5

MEAN MONTHLY MIXING RATIO (GRAINS/LB.)

Location	1941-1960											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ottawa	9	10	16	26	42	63	73	70	54	36	23	13
Windsor	17	16	23	33	48	74	84	83	65	44	30	20
North Bay	8	10	14	22	38	58	70	66	52	35	22	12
Toronto	15	16	19	28	41	62	75	74	57	41	28	18

Note:
It would be appropriate to discuss regional variations in Ontario's climate in general terms to supplement this statistical data. This would require, however, a detailed understanding of the climatic conditions throughout Ontario. It would be the subject of a future, supplementary project.

3.5 Obtaining Climatic Information

Historical climatic information for Ontario is available from a number of sources ranging from local airports to the Federal Government Service. The smaller weather stations will generally only record information on such basic climatic factors as temperature, wind, precipitation and humidity. The more established facilities used for scientific as well as technical measurements will likely have equipment for measuring various types of solar radiation, bright sunshine, and pollution, in addition to the basic climatic factors.

The primary source of climatic information in Ontario is the Atmospheric Environment Service which publishes information and booklets on Ontario's climate. Requests for information or data published by this organization should be directed to:

Scientific Services Division
Ontario Region
Atmospheric Environment Service
25 St. Clair Avenue East
3rd Floor
Toronto, Ontario
M4T 1M2
Telephone (416) 966-5554

3.5.1 Climatic Observing Stations

The observing stations that record climatic information in Ontario are shown in Figure No.3.11 The accurate location of these stations can be obtained from the Atmospheric Environment Service. The majority of these stations report maximum and minimum temperatures and precipitation.

The Atmospheric Environment Service operates a number of stations in Ontario (see Figure 3.12) where readings are taken on an hourly basis, 24 hours a day, 7 days a week. These stations typically report on cloud height and amount, atmospheric pressure, visibility, temperature dewpoint (a measure of humidity) and wind speed and direction.

Solar radiation measurements are taken at six locations in Ontario (Figure 3.13) and are published monthly by the Atmospheric Environment Service. As these sites are widely dispersed throughout Ontario and may not reflect local conditions, two other surrogates can be used to estimate available solar radiation. Hours of bright sunshine, as recorded at thirty-eight sites (Table 3.6) in Ontario can be used as can hours of colid cloud cover which is available at twenty-eight locations. Mean monthly values of these variables are available in the following AES publications.

- Daily Bright Sunshine 1941-1970. B. Yorke and G. Kendall
- Cloud Cover - Climatic Normals, Volume 3.

FIGURE NO.3.11

CLIMATE OBSERVING STATION IN ONTARIO
(AES 1977)

FIGURE NO.3.12

LOCATION OF HOURLY OR SYNOPTIC
METEROLOGICAL STATIONS (AES 1980)

FIGURE NO. 3.13

LOCATIONS OF SOLAR RADIATION MEASUREMENT IN ONTARIO

Source: AES, 1980.

TABLE 3.6

LOCATION OF SITES MEASURING
BRIGHT SUNSHINE IN ONTARIO

Albion Field Centre
Burketon McLaughlin
Delhi CDA
Elora Research Station
Guelph Arboretum
Harrow CDA
Kapuskasing CDA
Hamilton, RBG
Kemptville
Honey Harbour Beausoleil
Lindsay Frost
London Airport
Moosonee
Mount Forest
New Liskeard
North Bay Airport
Ottawa CDA
Ottawa International Airport
Petawawa Forest Exp Station
Sarnia Airport
Sault Ste. Marie Airport
South Bay Mouth
Sudbury Airport
Toronto Bloor Street
Toronto Met. Research
Turbine
Vineland Station
Wiarton Airport
Cornwall Ontario Hydro
Caribou Island
Ottawa NRC

Source: AES 1981.

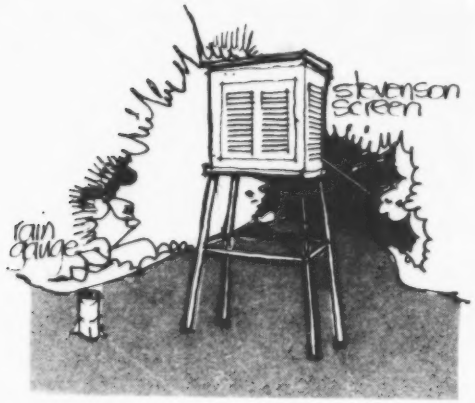
3.5.2 How Climatic Data is Collected

The traditional weather station is generally equipped with thermometers to measure air temperature and a rain gauge. The thermometers are usually maximum-minimum thermometers (which are read twice a day) or a thermograph (which records air temperatures on a graph). These are housed in a white, louvered box called a Stevenson screen (Figure 3.14). This is to allow air flow into the box so that measured temperatures are similar to ambient air temperatures. The white paint reflects solar radiation, reducing overheating on the Stevenson screen. Since the nature of the surface strongly controls air temperature, Stevenson screens are supposed to be placed 1.2 - 1.8 m (3.9 - 5.8 feet) above a short grass surface. These standards are observed to ensure that "regional" air temperatures are measured, not temperatures due to local variations. Screens placed in parking lots or on building roofs are of little value since they are likely measuring air temperatures only associated with those surfaces.

FIGURE NO.3.14

STEVENSON SCREEN AND RAIN GAUGE

(National Weather Service)



The rain gauge, usually just a funnel within a metal container, is read at the same times (8:00 a.m. and 4:00 - 5:00 p.m.) as the temperature measurements.

Unfortunately, the traditional weather station just described meets few of the requirements of the energy conscious planner. The planner needs information on local variations of (1) solar radiation or bright sunshine hours (2) wind speed and direction, (3) air temperature and (4) humidity (minimally important).

Solar radiation or bright sunshine is probably the most important and can be monitored with instruments designed to measure either variable. Measuring bright sunshine is the least expensive. The instrument records the time during which solar radiation is intense enough to burn a strip in specially treated paper. It usually needs to be read once a day and may be damaged by vandalism unless protected. Solar radiation equipment is more expensive and requires a recorder to store data. The sensor is delicate and also needs protection from vandalism. In either case, to determine differences in available solar radiation between locations requires data for a minimum of one year.

Wind Speed and Direction

Measurement of wind speed and direction is generally done with an anemometer (wind speed) and wind vane (wind direction). Anenometers should be placed in open areas at a height of 10 m (32.5 feet). This allows comparison with other wind data since A.E.S. measures standard wind speed and direction at this height. This type of instrumentation may complement a fairly "permanent" weather station, where bright sunshine hours and air temperatures are monitored as well. Alternately there are inexpensive hand held anemometers available which can be used in a variety of places within the settlement at the same time to determine variations in wind flow. Inexpensive streamers in combination with a

compass can be used to determine wind direction. This approach is very flexible and if sufficient staff is available, may be a good alternative to an expensive "permanent" weather station. As long as wind measurements are taken at consistent heights with similar amounts of open area around each instrument, then realistic results can be obtained. Since the planner wants to protect against cold winter winds and enhance winds under hot, humid conditions the planner should have a general idea of local wind patterns under these two regional wind cases. Thus for many parts of Ontario, this will mean sampling under conditions of strong NW, W, or N winds (exact direction depends on the area) - for the winter case and under light W, SE, or SW winds (exact direction depends on the area) - for the summer case. By comparison of local wind data with wind information at the same height at a nearby airport (if available) the planner can determine how the urban area modifies wind flow and which areas proposed for development are best suited from an energy conservation standpoint. As well, sampling should be done under light regional wind conditions when local winds develop. For instance, wind direction information will indicate areas subject to cold air drainage (i.e., places to avoid locating dwellings) and how far lake breezes penetrate into lakeshore urban areas.

Temperature

Temperature measurements can be taken with a Stevenson screen. Although this provides a standardized method of obtaining air temperatures it is fairly elaborate and expensive. For planning purposes, mobile temperature traverses are suitable and avoid permanent installations. They can be undertaken at various degrees of sophistication ranging from using a standard thermometer placed outside a vehicle which can be read by flashlight at night to a thermister aspirated by a fan with a recorder. As long as the thermometer is shielded with aluminum foil or mylar tape and oriented such that air flows easily around the bulb, then reasonable results can be obtained.

The selected technique should be applied to all the major land use patterns and topographic features within the settlement. This will enable the planner to determine the effect of the existing urban form and show the degree to which valleys, escarpments, water bodies and other natural features modify local air temperatures. The traverses should be obtained under a variety of weather conditions to indicate the range of control each feature has on air temperature. For instance, measurements should be made under clear skies and calm conditions both in winter and summer by night and by day. Traverses under cloudy, windy conditions will yield different, probably much smaller ranges in temperature.

An alternative method of determining air temperature variations is by infrared photographs taken from aircraft. This usually involves considerable expense but yields a permanent record of temperature patterns.

Humidity

Since humidity is of minor concern in Ontario's latitudes, only one method of measurement will be outlined briefly. Many weather stations utilize phychrometers, which consist of two thermometers, the bulb of one covered by a muslin wick. This wick is kept moist by an attached water container of distilled water. Since evaporation occurs on the thermometer with the wick, this cools the bulb and this wet bulb thermometer records a lower temperature. Aspiration (with a fan or by rotating the psychrometer rapidly) usually provides an adequate opportunity for evaporation to occur. Tables or charts are used to determine relative humidity from the difference in wet and dry bulb temperatures. In dry air there is a large temperature difference (due to rapid evaporation from the wet bulb) and this implies a low relative humidity. When the air is moist, little evaporation occurs from the wet bulb, resulting in a small wet/dry bulb temperature difference. This indicates a high relative humidity.

3.5.3 Obtaining Information for Isolated Locations

In most cases, regional data will probably satisfy the requirements of the land use planner.

In areas where there is not a climatological station in the immediate vicinity or where the meso- or microclimate modifies the regional climate, it may be desireable to establish a small station with a rain gauge and Stevenson screen. However, much of the sunlight and solar radiation data that would be useful to a land use planner is not easily or inexpensively obtained. Climatic conditions can also vary substantially from year to year. The basis of documented climatic conditions is generally reading over a period of 30 years or more. Considerable caution should be taken when making decisions based on data obtained over a short period.

A more severe approach to identify a similar condition in an area where climatic information is available from a dependable source. Slight modifications can be made, based on discussions with the operator of the local climatological station.

In summary, the most suitable climatic data for energy conservation purposes is likely not readily available and therefore will need to be gathered. Because longer term data should be obtained for solar radiation or bright sunshine hours, a small network of sensors should ideally be set up, particularly where development is slated to occur. Wind speed and direction and temperature (and humidity if desired) are most easily handled by temporary observations under those weather conditions of interest. Because of the nature of wind fluctuations, these measurements should be taken at exactly the same time in a variety of areas within the settlement. Temperature (and humidity) measurements can be made by mobile traverse through a route covering those areas of interest. A correction for changes in air temperature due to the length of time needed to do the traverse can be applied if needed. This requires that the route crosses itself near the beginning and again toward the end to determine if heating or cooling has occurred during the traverse.

Techniques for Planning with Climate

4.0 TECHNIQUES FOR PLANNING WITH CLIMATE

The annual variations of climate in Ontario deviate from the human comfort zone for a substantial portion of the year. Planners must, therefore, develop techniques to plan the environment to enhance the beneficial climate conditions and to avoid or ameliorate undesirable conditions. This chapter deals with several climatic variables including solar radiation, wind, temperature and humidity. The potential for vegetation to modify meso- and microclimatics is also investigated. The objective of this chapter is to present a preliminary introduction of techniques that planners can use to control and modify climatic conditions.

4.1 Solar Orientation

In designing with climate the most benefit can be realized by orienting buildings to obtain the greatest heat gain from the sun. This condition can be realized by facing large window areas to the south, east and west. Within limits, the increased natural light and sunshine will be pleasant for the buildings' inhabitants and the additional heat generated will reduce the building heating load. In the northern areas of Ontario this will be beneficial on a year round basis while buildings in southern Ontario will benefit from October to April. The influence of orientation on the sun received by a building is illustrated in Figure 4.1.

Shading can be controlled by sun shadow analysis, done prior to plan approval, and by varying the building setback where structures are aligned north-south. On east-west streets, building height should be controlled to maintain sunlight access potential (see Figure 4.3). Consideration must also be given to latitude as the southern areas of Ontario will have a slightly longer day with the sun higher in the sky (see Figure 4.2).

In southern Ontario, protection will be required from the summer sun to minimize a building's cooling load. Deciduous vegetation has proven the best natural protection. Where this is not feasible or available, shading must be provided. Experience has shown that external shading devices such as extended eaves, awnings and external blinds provide better protection than internal shading devices.

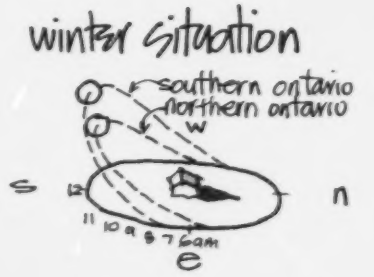
FIGURE 4.1

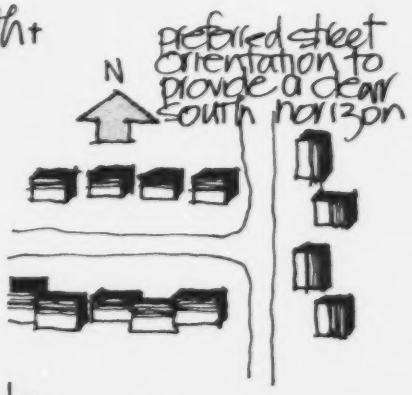
BUILDING ORIENTATION: SUNSHINE AND SHADE

•facing east + west.
sunshine all day on both faces summer + winter
n.face: afternoon sun morning shade summer + winter
s.face: morning sun afternoon shade summer + winter
•facing NW to SE.
•facing north + south.
n.face: early morning summer sun shade all winter
s.face: shade early morning sun rest of day in summer
•facing NE + SW.
n.face: morning sun afternoon shade summer + winter
s.face: afternoon sun, morning shade summer + winter

FIGURE 4.2

POTENTIAL SUNLIGHT COMPARISON: SOUTHERN VS. NORTHERN ONTARIO





Source: Ontario Ministry of Housing, A Guide to Residential Planning and Design in Small Communities, 1980.

The land use planner should attempt to ensure that the potential for heat gain through passive solar energy is provided for in the design and location of buildings. The subject of active solar energy systems is an extensive one and will not be addressed in this report. It should, however, be recognized that these systems will require solar access but are not necessarily tied to the location and orientation of the structures they heat. The installation of active solar energy systems will require the assistance of policy planners to ensure that future development does not interfere with solar access to these systems.

4.2 Wind Control

Wind can have a major impact on the comfort of pedestrians and the design and orientation of buildings. The effects of wind on people is described in Table 1. As wind speeds in excess of 5 m/s can cause discomfort, especially when combined with shading and low ambient temperatures, the planner should aim at keeping wind speeds below this velocity. To reach this objective, the land use planner must consider building orientation, massing of buildings and general topography.

Past emphasis has been placed on wind conditions created by large buildings in downtown urban settings. The canyon like streets which funnel wind (and increase speed) and tall buildings that create down-drafts and eddying effects at building corners all create an inhospitable environment for the pedestrian, especially in the winter months. To modify and improve this environment will be difficult in existing areas and will require the co-operation of politicians (policy), architects (design), specialized technicians (wind tunnel tests) and developers to ensure that new projects do not create similar environments or worsen existing problem areas.

Controls for wind in urban areas are generally architectural in nature, as flexibility in location and orientation is often limited by site constraints. Solutions such as arcades, canopies with parapets

and balconies are common responses to wind as well as other undesirable climatic conditions. Where major development is proposed, the municipality may request a sophisticated wind tunnel analysis to prove that an acceptable wind level can be attained under most conditions.

For low residential and industrial buildings, the orientation with respect to prevailing winds is not as significant as for downtown areas. Troublesome wind conditions can be altered by landscape planting, energy consumption improved through building design and structures placed to benefit from microclimatic conditions.

However, the land use planner should give careful consideration to the topography and general orientation of his site. The temperate-cool climate of Ontario places greater concern on winter conditions. Development should not be placed in depressions where cold air will pool or at the bottom of slopes that will be influenced by the downward flow of cold air. Cold winds will be channelled down valleys encouraging that buildings be massed with few openings oriented in the direction of the prevailing winds.

TABLE 4.1

EFFECTS OF WIND ON PEOPLE

Beaufort Number	Wind Speed m/s	Effect
0.1	0 - 1.5	No noticeable wind
2	1.6 - 3.3	Wind felt on face
3	3.4 - 5.4	Hair is disturbed, clothing flaps
4	5.5 - 7.9	Raises dust, dry soil and loose paper, Hair disarranged
5	8.0 - 10.7	Force of wind felt on body Limit of agreeable wind on land
6	10.8 - 13.8	Umbrellas used with difficulty Difficult to walk steadily
7	13.9 - 17.1	Inconvenience felt when walking
8	17.2 - 20.7	Generally impedes progress
9	20.8 - 24.4	People blown over by gusts

4.3 Temperature/Humidity Control

4.3.1 Air Temperatures

The air temperature both inside and outside affects human comfort and, in extreme conditions, our health. In our role as land use planners we should consider the effect of urban development on the ambient temperature and how the anticipated increase in temperature can be minimized or maximized as the case may be.

The increase in air temperature or heat island effect is a result of various factors. The increase in the absorption of solar radiation is due to the nature of surfaces (asphalt, concrete, steel, etc.) and a reduction in wind speed and vegetation. Altitude will also influence temperature, causing a drop of one degree for each 330 foot rise in summer and a drop of one degree for each 440 foot rise in winter.

Planning should consider policies which would achieve, in the long term, a spatial arrangement of buildings in the city so that the net result is a weakening of the heat island. Location in relationship to other buildings, parks, rivers and lakes can be critical. Planners should ensure that buildings do not block lake breezes that penetrate up city streets and between buildings to cool the adjacent area. Radial streets will enable wind to penetrate deep into the urban core from a number of directions throughout the yearly wind cycle. An aerodynamically rough urban surface will create turbulance, allowing wind to reach between buildings to disperse the build-up of heat (and pollution). However, under strong wind conditions or during cooler air temperatures, these circumstances are likely to have a negative impact on human comfort. A more desirable, as well as aesthetically pleasing approach, is to incorporate sufficient parks, green areas and trees in the city and encourage the use of high albedo, low thermal capacity building materials. This solution is common in Mediterranean and tropical environments.

As much of northern Ontario requires heating on an annual basis, planners should attempt to benefit from the heat island effect to reduce heating requirements and attain an acceptable level of human comfort over a larger part of the year. Encouraging an increase in terperature will also reduce the time that snow is on the ground and, in some cases, increase the length of the growing season.

4.3.2 Humidity

High humidity in combination with high temperatures can cause very uncomfortable conditions which generally require some form of air conditioning for relief. In general, these conditions occur during the summer months in sizeable urban centres and are difficult to control through planning. Any action to lower the urban air temperature will make the environment more comfortable.

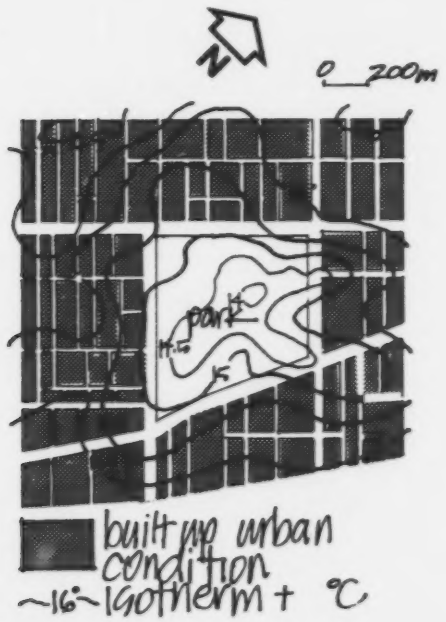
Research by Oke (1972) has shown that in general there is a small difference in the water-vapour content of urban and rural atmospheres; however, the lower relative humidities in towns will be an advantage when temperatures are high. The reason that urban parks and vegetated areas are cooler than they might otherwise be is due to the effect of evaporation rates. A study of evapotranspiration rates by Oke in Montreal is probably representative of most southern Ontario towns. The study clearly demonstrates the important role of evaporation and transpiration in cooling an urban area with even a small amount of vegetated area. The anticipated cooling due to evapotranspiration as a fraction of vegetated area is illustrated in Figure 4.4.

There will thus be a circulation of area around parks and vegetated open areas than will influence the immediate surroundings by cooling and cleaning the air.

The relative dryness of Ontario winters is primarily a problem of an indoor lack of moisture and must be dealt with on an individual building basis by introducing more moisture into the air. Should these conditions prevail outside when temperatures are above freezing, moisture can be provided through ponds and water fountains, however, this will also reduce the local air temperature.

FIGURE 4.4

SIMULATED EFFECT ON COOLING OF VARYING THE AREA OF A CITY COVERED BY EVAPOTRANSPIRING SURFACES



4.4 Use of Vegetation

In consideration of the fact that an extensive parallel study is being undertaken on the role of landscaping in reducing energy consumption, this section will present only a brief summary on this subject. The following material and sketches has been condensed from the American Society of Landscape Architects publication, Landscape Planning for Energy Conservation.

Basically, vegetation controls the sun's effect by filtration of the direct solar radiation, by control of the ground surface temperature and hence the amount of heat radiated from these various surfaces, either daily or seasonally, through the alteration of the ground temperature, through control of reflected radiation, and through total or major obstruction of the solar radiation itself. These effects are illustrated in the following drawings:

FIGURE 4.5

SUN CONTROL

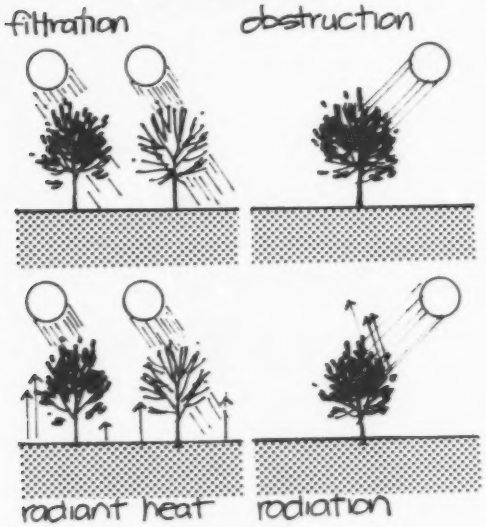
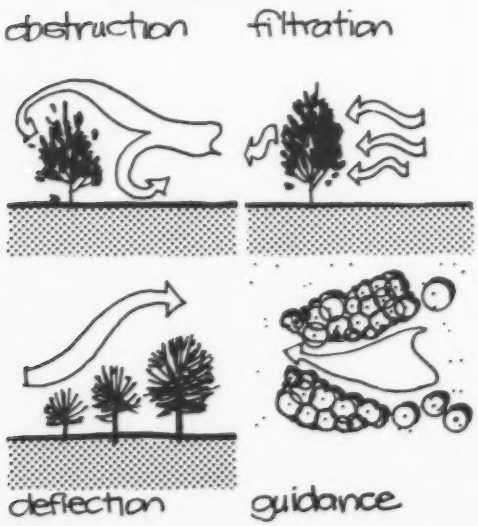


FIGURE 4.6

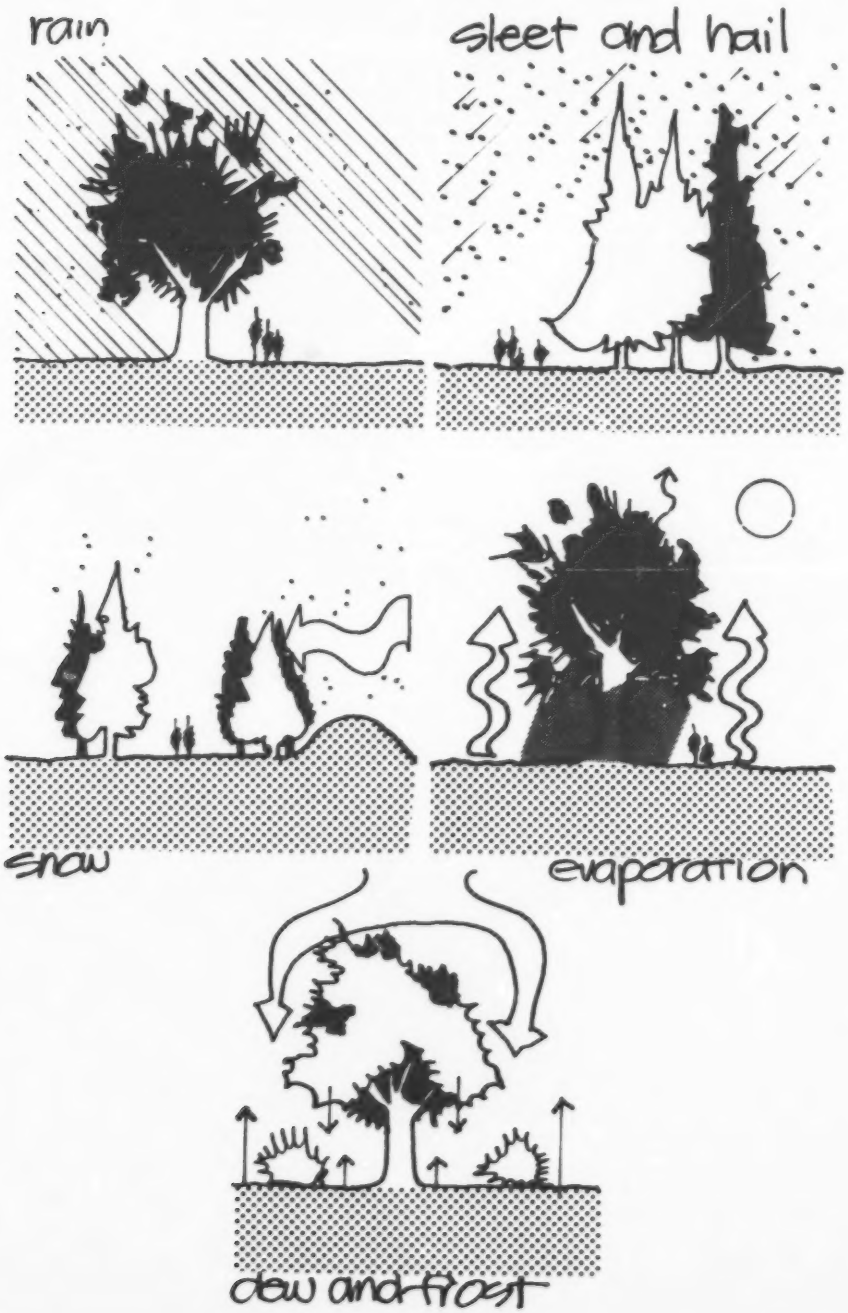
WIND CONTROL



In much the same way, precipitation in different forms is controlled to various degrees by vegetation. Plant materials control the impact of rain, sleet and hail, the position and amount of snow deposition, the intensity and location of dew and frost, and of the evaporation of moisture from the ground surface.

FIGURE 4.7

PRECIPITATION AND HUMIDITY CONTROL



Because plant materials control solar radiation, wind, precipitation and humidity, they control temperature in seasonal and in annual variations. As plant materials grow, they also control temperature variations, both dauring the day and at night.

FIGURE 4.8

TEMPERATURE CONTROL

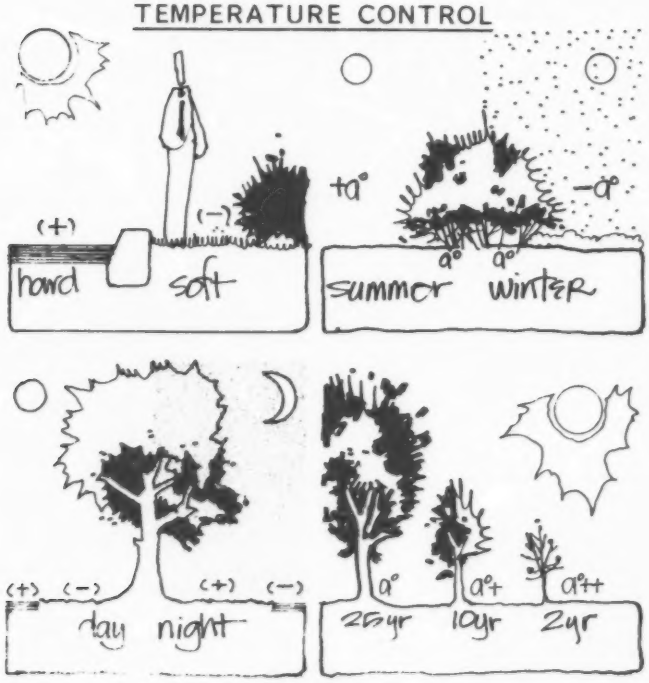
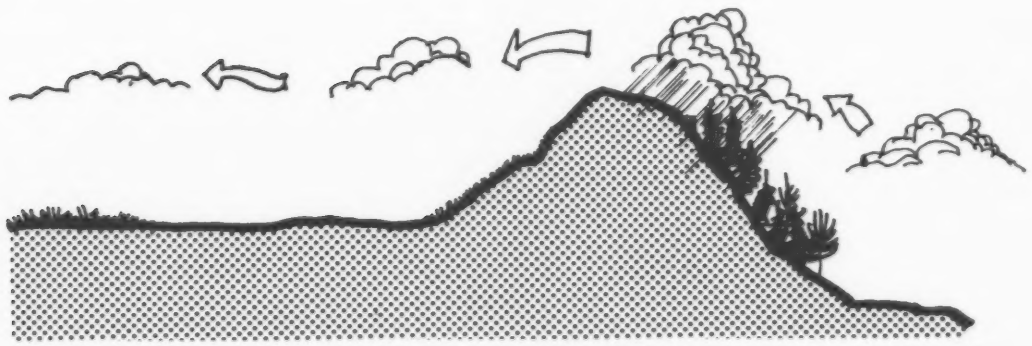


FIGURE 4.9

TOPOCLIMATOLOGY AND PLANT MATERIALS



The extent of the impact of vegetation upon the climate should not be underestimated. Vegetation may absorb over 90% of light falling upon it, reduce wind speeds in an area to less than 10% of that in the open, or increase them, reduce daytime temperatures by as much as 8 degrees Celcius, and, in certain situations, raise nightime temperatures.

Summarized, the principal uses of vegetation of special importance to the energy-conscious planner are:

1) Large and small trees and shrubs may be used to screen out undesirable winds; conifers should be used to control winter winds.

2) Trees may be used to channel winds, to increase ventilation in specific areas.

3) Plantings will reduce the accumulation of snow on the ground, and so may be used to shield a solar collection unit.

4) Vegetation, especially needle-leaved trees, may be used to capture fog, and thus increase sunlight reaching the ground or the collector unit.

5) Deciduous trees will screen out direct sunlight during the summer, to reduce required cooling loads, but allow it to pass through in the winter, reducing required heating loads.

6) Planted areas will be cooler during the day, and experience less heat loss at night.

Thus it can be seen that parks, gardens, lakes and other open spaces, can play an important role in reducing the surrounding air temperature, encouraging evaptranspiration and creating air-flows. A well thought-out park system and general landscaping

policy will contribute significantly to a pleasant urban climate while also providing aesthetic relief and the potential for active and passive recreation areas. Depending on the nature of the vegetation and how it is planted, the ambient noise level can be reduced and the local level of pollution in the air improved.

4.5 Basic Climatic Site Analysis

The climatic information that a land use planner should obtain (or request) to evaluate a site or area is listed below.

1. Climatically protected areas on the site
   - areas protected at certain times of the day or year
   - areas protected by topography
   - areas protected by vegetation

2. Climatically exposed locations on the site
   - areas exposed to sun or wind
   - areas exposed primarily in winter
   - areas exposed primarily in summer
   - areas exposed all seasons of the year

3. Solar radiation patterns on the site
   - daily and monthly
   - seasonal
   - impediments (e.g., vegetation which may cover the site or shadow certain areas on the site)

4. Wind patterns on the site
   - daily and monthly
   - seasonal
   - impediments (e.g. thick vegetation or underbrush which may block air movement on or through the site)

5. Precipitation patterns on the site
   - fog movement, collection or propensity patterns
   - snow drift and collection patterns
   - frost "pockets"

6. Temperature patterns on the site
   - daily and monthly
   - seasonal
   - warm areas
   - cold areas

7. Water or drainage patterns on or across the site
   - seasonal air or water flow patterns
   - daily air or water flow patterns
   - existing or natural impediments to air or water flow patterns

The majority of this information will be available from the Atmospheric Environment Service; however, climatic information is not generally collected specifically for use by planners and some relevant data may be omitted. Additional information is usually available from the closest observing station or airport.

4.6 Summary of Climatic Techniques for Site Planning

The best approach to climatic conditions is to obtain a good site, the proper orientation of buildings and the appropriate architecture. However, these problems may not have been initially addressed correctly or be out of the control of the designer. In these situations it will be necessary, if possible, to correct errors or deficiencies at the site planning or design stage. The following summary of climatic techniques provides some suggestions as to how this might be accomplished.

1. In order to make site or an area warmer, site planning should:

   - emphasize and utilize all of the maximum solar exposures on a particular site
   - provide for paved areas and rock or masonry surfaces on south facing slopes or surfaces
   - provide for structural or vegetational outdoor canopies to reflect out-going radiation at night
   - provide, allow for or retain "sun pockets" which are potentially on a site or already in existence
   - provide for wind breaks and cold airflow diverters either with vegetation, walls, fences or the architecture itself
   - locate paved areas and terraces on the south side of structures and remove shading devices during the day
   - use heat retaining structural materials such as concrete, masonry and wood
   - remove shade or shading devices from the south and west sides of a structure
   - locate outdoor terraces, used in the afternoon, on the south or southwest sides of structures
   - remove water features or water bodies
   - prune and thin existing shade trees to allow for maximum solar penetration.

2. In order to make a site or an area cooler, the site planner should:

   - make extensive use of shade trees as an overhead canopy

- use vines, either on an overhead trellis or on south and west facing walls
- use overhangs, trellises, arbors or canopies where possible (this makes an area cooler in the daytime and yet warmer at night since it limits the release of colder air into the colder night air)
- use ground covers or turf on earth surfaces rather than paving
- prune lower branches of tall trees and remove or thin lower trees and shrubs to improve and increase air circulation
- provide for evaporative cooling from sprinklers and pools
- use areas on the north and east sides of structures for outdoor activities
- remove windbreaks, either natural or man-made which would limit or hinder airflow especially during the warmer months.

3. In order to make a site or an area less windy or breezy, the site planner should:

- use extensive vegetational, man-made or earth formed windbreaks, baffles, diverters or wind direction or guidance devices
- use, where possible, outdoor living areas which are semi-enclosed either by the architecture or landscape elements
- stop pruning or thinning lower branches on tall trees or under-storey vegetation in heavily wooded areas

- locate outdoor activities in areas protected by natural windbreaks
- excavate and place activities partly below ground level in order to use the earth to block winds and to require lower additional windbreaks.

4. In order to increase the wind flow and the cooling effect of wind on a site or in an area, the site planner should:
   - remove all restrictions to natural air flow patterns on a site
   - prune all lower branches of taller trees
   - curtail and limit all low plant growth between 1 foot and 10 feet high which would inhibit or limit wind flow
   - build decks or platforms on the windiest areas on the site in order to take advantage of natural breezes
   - create natural wind tunnels or breezeways using either plant materials, earth forms, architecture, fences or walls
   - locate activities or areas on the sides of a valley wall to take advantage of the day and night wind flow patterns.

5. In order to make a site or an areas more humid, the site planner should:
   - allow standing water to remain on the site and limit drainage to the minimum
   - encourage or increase overhead planting which slows evaporation and adds moisture through transpiration from the plants

- add, to the extent possible, pools, fountains, sprinklers and waterfalls which increase the moisture in the air. The sound of water also increases the sense of coolness and humidity
- use turf or ground cover on all surfaces where possible rather than paving
- use relatively low windbreaks, below four feet in height to preserve moisture transpired by turf or ground cover
- use natural wood chip or peat mulch under all plantings.

6. In order to make a site drier, a planner should:

- maximize solar radiation exposure on the site and reduce shading devices
- maximize air flow and ventilation across the site
- provide an efficient water drainage system for ground water and for storm drainage
- pave all horizontal ground surfaces
- reduce plantings especially ground covers and turf
- eliminate all water bodies, pools and fountains.

Source: Landscape Planning for Energy Conservation.

Land Use Planning with Climate

5.0 LAND USE PLANNING WITH CLIMATE

5.1 Approach

Climatic information can be incorporated into planning of land uses in urban areas to meet the following goals:

- conserve energy
- minimize environmental impacts
- minimize costs
- design for human comfort

These goals can be met to varying degrees by the proper use of climatic factors in land use planning. Climate design is discussed for each of the following land uses in the chapter below:

- Residential uses
- Commercial uses
- Industrial uses
- Recreational uses
- Transportation uses
- Waterfront uses

The importance of each of the major climatic factors is discussed for each land use.

Two basic approaches for planning with climate are appropriate in Ontario. They are based upon the cool climatic region of Northern Ontario and the temperate climatic region of Southern Ontario.

5.1.1 Northern Ontario

In cool climatic regions, such as Northern Ontario, Victor Olgyay suggests that the general objectives for planning with climate should be:

- increase heat production
- increase radiation absorption and decrease radiation loss
- reduce conduction and evaporation heat loss

The optimum urban structure in this region could be described as an insolated dense layout, such as shown in Figure 5.1 (B and C). The overall design should provide a sheltering effect against winds.

Larger building units may be grouped close together but spaced to utilize passive solar heating effects. The houses tend to be joined to expose less surface to heat loss.

In general, public spaces should be wind-sheltered, open, with periodically shaded areas. The best housing sites have SSE slopes with the middle of the slope preferred to prevent excessive wind effects and to avoid cool air pools. (Olgyay, P.155).

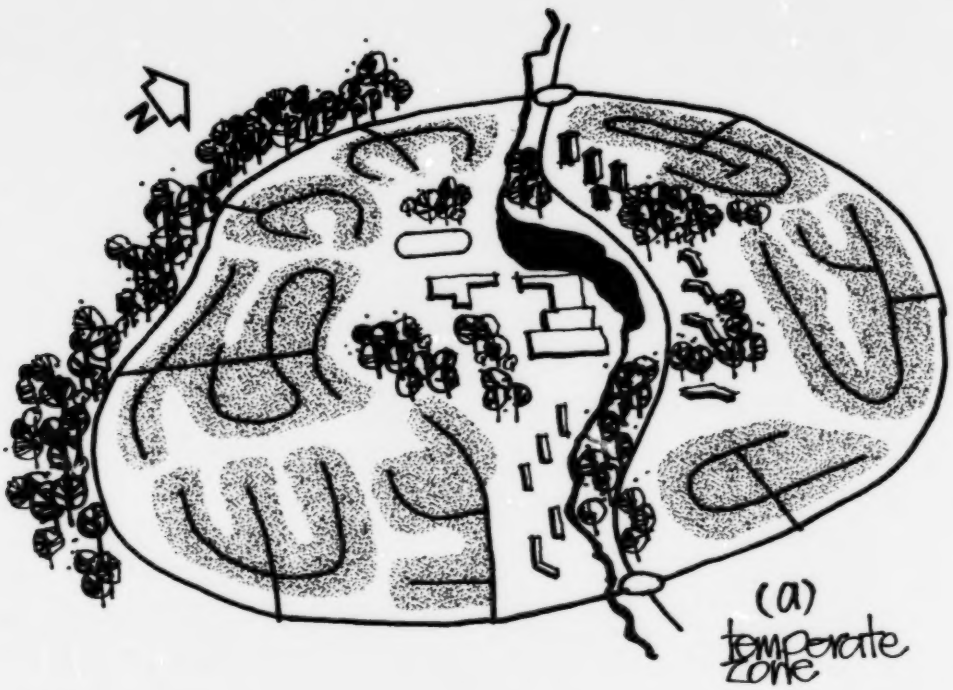
5.1.2 Southern Ontario

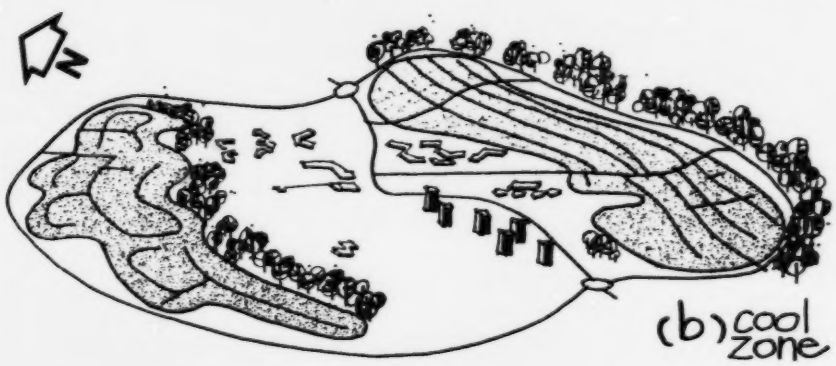
Temperate climatic regions, such as Southern Ontario, experience both underheated and overheated periods during substantial portions of the year. Olgyay suggests that objectives for planning for climate in this area should include:

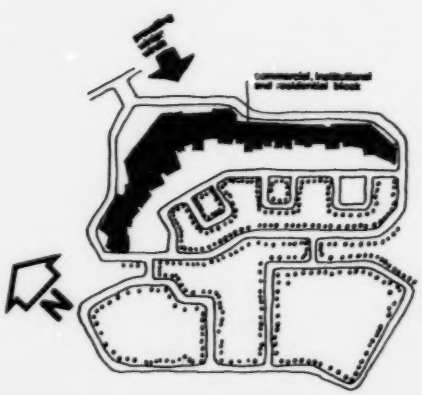
- establish a balance between the seasonal effects of heat production, radiation and convection
- take advantage of the freedom of design available because of lower climatic stress.

This region is generally subjected to less extreme climatic stress than Northern Ontario and more freedom is available for urban designers. The preferred urban structure could include an open and free layout of buildings, based mainly on the prevailing requirements of the underheated winter period, such as solar heat gain; however, the characteristics of the overheated summer period must be considered as well.

FIGURE 5.1 URBAN FORM







(c)
arctic
zone

fermont, Quebec

In general, open lawns and trees are desirable in public spaces. Roads should be arranged in a manner which avoid winter winds and channels summer breezes. The best housing sites usually have slopes facing just east of South with the upper and lower inclined portions usable if wind sheltering is provided. (Olgyay, p.161).

5.1.3 Land Use Considerations

Land use planning is often an incremental process which considers changes to one land use at a time. The importance of any climatic factor in the conservation of energy will vary according to the type of land use proposed. Similarly, the techniques which are most effectively used to meet the objectives described in Section 5.1 will be different for each land use category. When dealing with a specific change in land use, urban planners and other designers may wish to make use of specific techniques to produce a plan which is sensitive to the local climate.

5.2 Residential Uses

5.2.1 Solar Radiation

Building orientation to maximize the potential for utilizing solar radiation is very important. Most people prefer windows and these can be used to reduce winter energy use by placing them on the south side of the house. Also, shading in summer can be accomplished by proper window overhang construction and landscaping, thereby minimizing the possibility of overheating (Figure 5.2). Larger residential buildings, such as apartment buildings may cause some problems since they cast long shadows and require awnings or inset windows to reduce the effect of overheating. The necessary awning size or inset dimensions will vary with latitude. In general, north and west facing windows areas should be minimized.

FIGURE 5.2

USE OF WINDOW OVERHANG

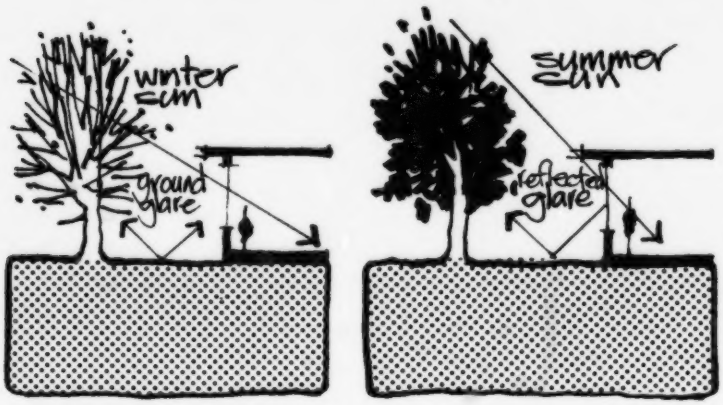
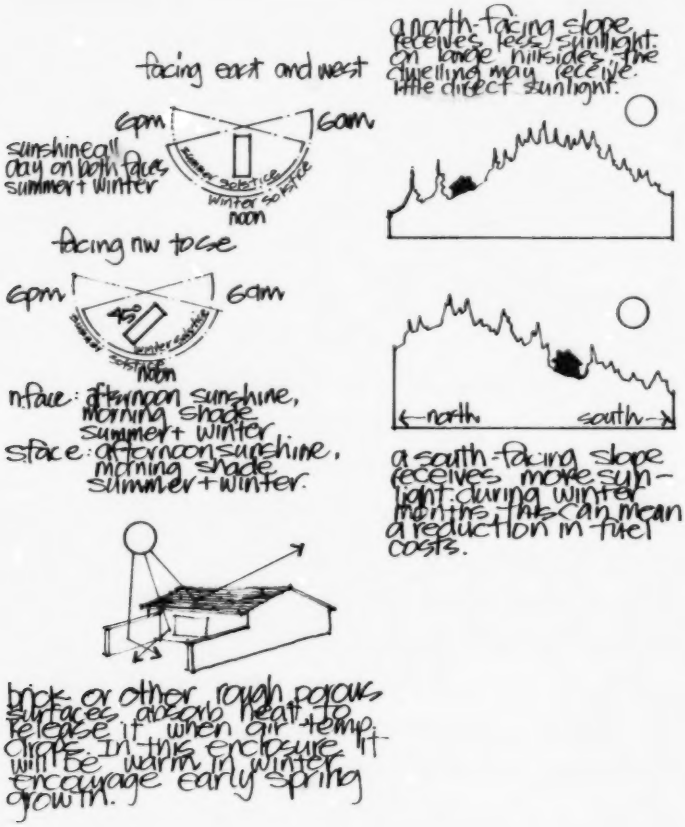


FIGURE 5.3

USE OF SOLAR RADIATION IN DESIGN


facing east and west
6pm
6am
sunshine all day on both faces, summer + winter
summer solstice
winter solstice
noon
facing nw to se
6pm
6am
45°
noon
nface: afternoon sunshine, morning shade summer + winter
sface: afternoon sunshine, morning shade summer + winter.
a north-facing slope receives less sunlight: on large hillsides the dwelling may receive little direct sunlight.
north
south
a south-facing slope receives more sunlight during winter months. this can mean a reduction in fuel costs.
brick or other rough porous surfaces absorb heat to release it when air temp drops. in this enclosure it will be warm in winter encourage early spring growth.

5.2.2 Wind Speed and Direction

An awareness of the prevailing winter winds is very important as high wind speeds enhance winter heat loss. By manipulating vegetation or using terrain wisely, energy required for home heating can be conserved. This is done by using south slopes to protect housing from north-west and north winds and avoiding ridge tops.

Because of the heights to which apartment buildings extend, surface control of wind is not as successful as for lower buildings. Again, however, south slopes are best. The orientation of buildings to allow cool summer breezes to penetrate in and around structures will reduce air conditioning requirements. The use of wider streets, which are carefully aligned to catch the prevailing summer breeze, will aid in natural ventilation.

5.2.3 Temperature

Temperature is a very important factor in residential design. Generally, south slopes will be warmest and north slopes, coldest. However, since under clear skies and light wind conditions, cold air will collect in depressions and valley bottoms, avoiding these areas will save energy in the winter.

Taller buildings have the ability to create heat islands which will reduce winter heating requirements in these areas. The use of parks near densely populated areas will act to reduce summer temperatures and air-conditioning requirements in these areas. In addition, the utilization of water bodies to cool urban areas will have the same influence. These effects are most pronounced for residential areas since occupancy is 24 hours per day, whereas for the rest of the land use categories, occupancy is usually limited to 8 to 12 hours per day.

FIGURE 5.4

DESIGNING WITH WIND

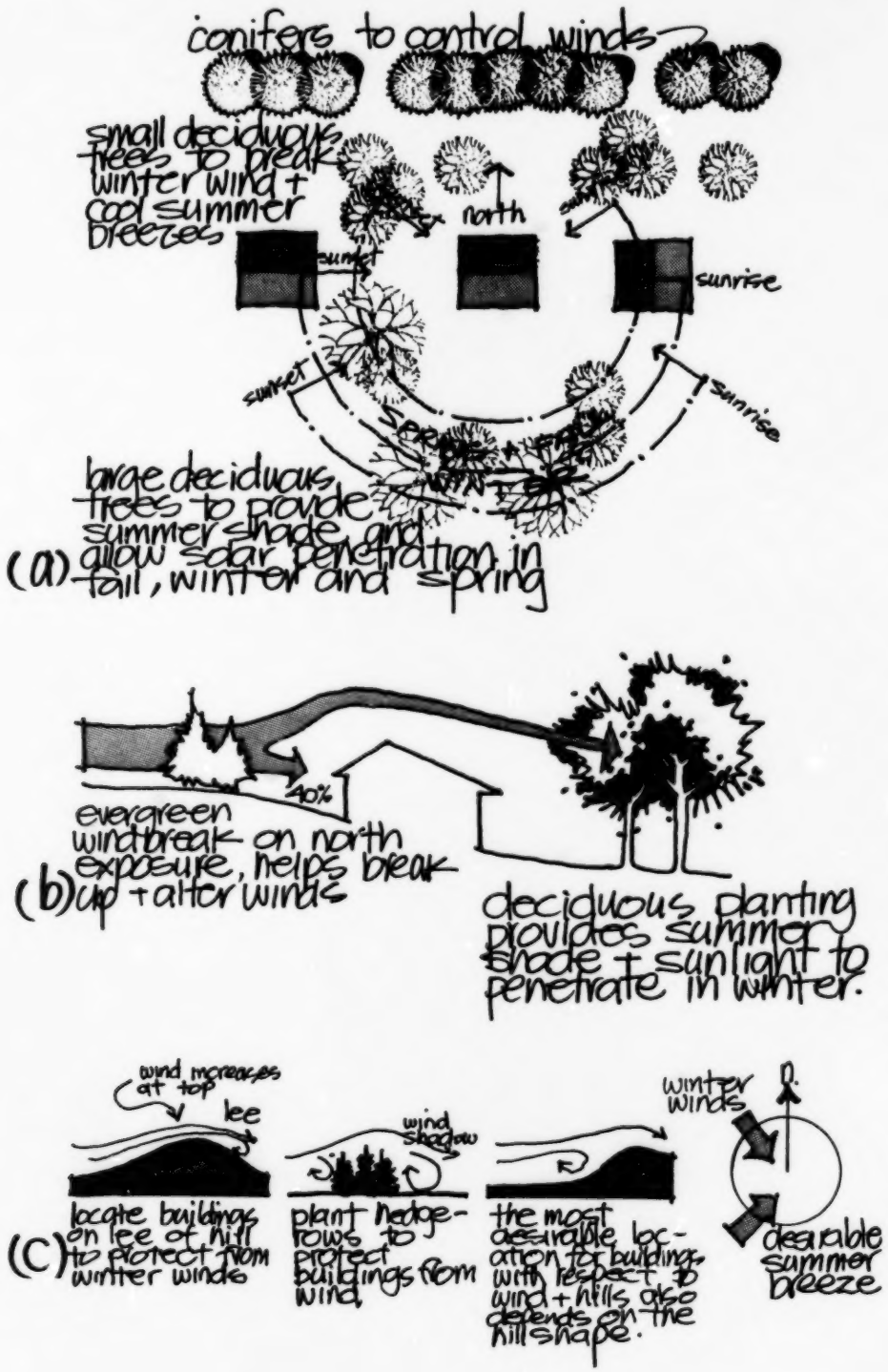
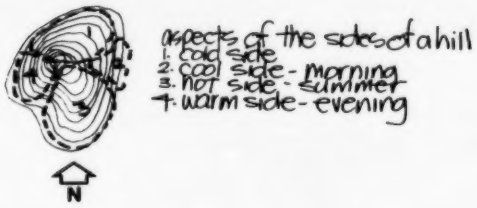

conifers to control winds
small deciduous trees to break winter wind + cool summer breezes
north
sunset
sunrise
sunset
sunrise
large deciduous trees to provide summer shade and allow solar penetration in fall, winter and spring
(a)
40%
evergreen windbreak on north exposure, helps break up + alter winds
(b)
deciduous planting provides summer shade + sunlight to penetrate in winter.
wind increases at top
lee
wind shadow
winter winds
desirable summer breeze
locate buildings on lee of hill to protect from winter winds
plant hedgerows to protect buildings from wind
the most desirable location for buildings with respect to wind + hills also depends on the hill shape.
(c)

FIGURE 5.5

ASPECTS OF A HILL



5.2.4 Humidity

Humidity only really becomes significant when combined with high air temperatures causing an increased air-conditioning load. At present there is little available information on how urban park areas affect humidity levels.

5.3 Commercial Uses

5.3.1 Solar Radiation

Solar radiation is a very important climatic design function in commercial areas. With glass a common exterior finish of commercial buildings, use can be made of available winter sun to reduce space heating requirements. Inset windows or overhangs should be used to prevent summer overheating. Once again, north and west-facing window areas should be minimized wherever possible.

5.3.2 Wind Speed and Direction

The importance of wind speed and direction in commercial areas depends upon the size of buildings with taller structures more difficult to shelter. Terrain protection and vegetation sheltering will work for lower buildings.

5.3.3 Temperature

Temperature may be an important design factor in commercial areas. Commercial areas may create their own heat islands, especially in large complexes such as central business districts and major regional shopping centres. These areas will show reduced energy consumption in winter because of warmer external temperatures. In southern Ontario, it may be advantageous to use summer breezes to ventilate these areas and reduce air conditioning loads. Large parks and water bodies may also be used to reduce the level of human discomfort during the summer months.

5.3.4 Humidity

Humidity control measures are of low importance in commercial areas.

5.4 Industrial Uses

5.4.1 Solar Radiation

The importance of solar radiation depends in large part on the type of industry and number of windows in each building. Where industrial buildings have large glazed areas, proper orientation may result in substantial energy savings. In these situations, window overhangs and tree planting should be used to reduce summer overheating.

5.4.2 Wind Speed and Direction

The importance of wind depends upon the number of north- or west-facing windows in an industrial building. If there are few of these windows it may be advantageous to place industrial development upon north slopes which are unfavourable for many other land uses.

Shelter belts of trees may be used to block cold winter winds and channel cool summer breezes around the building, thus reducing energy requirements for heating and air-conditioning.

Wind speed and direction are important factors in the dispersal of atmospheric pollutants from industrial sources. Noxious land uses are often located on an urban area's leeward margins as defined by the prevailing wind. This is not necessarily the best strategy, as the prevailing wind is usually associated with strong, turbulent airflows which disperse pollutants. A more satisfactory approach would be to locate noxious industries on the leeward portion of a city, as defined by the wind direction during periods of inversions, when the worst concentrations of pollutants often occur.

5.4.3 Temperature

Local temperature differences may be important in reducing building energy uses in certain types of industry. Heavy industrial areas, such as steel works, often release large quantities of heat through their production processes. This extra heat causes local heat islands and will reduce winter heating demands in these areas, provided that steps are taken to ensure that the heat island is not dispersed by winds in the winter.

5.4.4 Humidity

Humidity is of low importance in the planning of industrial areas.

5.5 Recreational Uses

5.5.1 Solar Radiation

Buildings designed for recreational uses may be oriented to use solar radiation for space heating purposes in the same manner as residential dwellings. Solar radiation can be advantageously used to heat the water in both indoor and outdoor swimming pools. Outdoor pools should not be overshaded by surrounding buildings or trees.

Sunshine is very important in the location of major outdoor recreation facilities. Local micro-climatic radiation should be investigated prior to the siting of major regional parks or facilities. In addition, playing fields and other outdoor recreational spaces should be oriented to avoid interference by evening sun.

5.5.2 Wind Speed and Direction

Recreational buildings can be sheltered in the same manner as residential dwellings. Outdoor recreational facilities may be sheltered from winds using vegetation and new buildings.

5.5.3 Temperature

Local variations in microclimate may be used to extend the season for many outdoor recreational facilities.

Vegetated open spaces such as parks, ponds and gardens should be placed near areas of high residential density which will provide recreation and cooler temperatures thereby reducing air conditioning demand during summer months. Trees should be placed along all streets to provide shade and reduce surface temperature.

5.5.4 Humidity

Humidity is of low importance for most recreational uses. However, major spectator facilities should not be placed in areas which are frequently subject to fog or mists because of local climatic variations.

5.6 Transportation Uses

5.6.1 Solar Radiation

The number of hours of sunshine is very important in the location of major air transportation facilities. In addition, solar radiation may be used to reduce heat loads in major transportation buildings.

To improve human comfort, pedestrian facilities should be located in a manner such that they receive direct sunlight in winter and that some shade is available in temperate zones during the summer months. The use of street awnings and arcades has been proven successful in several urban areas.

5.6.2 Wind Speed and Direction

Wind speed and direction are very important in the location of major air transportation facilities. Local wind conditions which lead to the build-up of snow may make both surface and air transportation facilities unusable.

Wind speed and direction are particularly important in the design of pedestrian facilities, especially in major building complexes and central business districts. Wind tunnel testing of models of proposed development has proved to be an effective design aid in this area and is now required in several Canadian cities.

Public road allowances should be located in a manner which uses cool summer breezes to ventilate the urban heat island and blocks cold winter winds. Roads which experience a high volume of vehicular traffic should be located in rights-of-way wide enough so that the wind can disperse local concentrations of air pollutants during periods of atmospheric conversion. Wind speeds of approximately 27 kph are required for this purpose.

5.6.3 Temperature

Surface temperature is considered in the design of airports because high temperatures may create localized problems with air pressure which affect aircraft when taking off.

5.6.4 Humidity

The occurrence of fog is very important in the location of air transportation facilities. In addition, areas of frequent fog should be taken into consideration in planning of major surface transportation facilities.

5.7 Waterfront Uses

Many urban areas in Ontario are located adjacent to a major lake or body of water. Mixed use developments in these areas require careful planning with relation to the local microclimate.

5.7.1 Solar Radiation

A lake breeze during the day often serves to maintain clear skies over the waterfront. These areas thereby obtain a larger quantity of unobstructed sunlight. Urban areas on the north shore of lakes may make good use of the unobstructed access to waterfront areas to reduce heat loads in winter months.

5.7.2 Wind Speed and Direction

Wind speed and direction are very important in the planning of waterfront areas. Winter recreational areas must be wind screened to block the prevailing winds. Summer recreational areas should be planned to allow penetration of cooling breezes during that season.

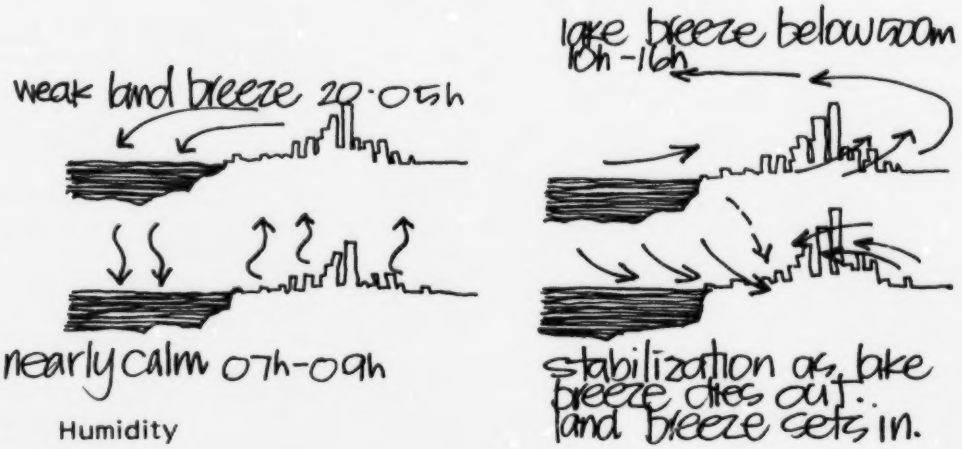
Buildings in a waterfront area are particularly susceptible to winter heat loss because of high wind speeds. Where possible, the lower buildings and pedestrian areas in a waterfront development should be sheltered from the winter winds.

5.7.3 Temperature

Lakes tend to moderate extreme temperatures in the adjacent waterfront areas (see Figure 5.6). However, this situation tends to keep many Ontario waterfront areas in near freezing temperatures during the winter, increasing the number of freeze-thaw sequences and making maintenance of walkways and stairs a problem. Consideration may have to be given to heated or enclosed walkways, regular sanding or use of coloured surfaces to utilize sunshine in melting snow and ice.

FIGURE 5.6

DIURNAL MODEL OF LAKE BREEZE



5.7.4 Humidity

Fog and mist are more likely to occur in a waterfront area than in any other portion of a city. Land uses which are sensitive to these conditions should not be located in waterfront areas.

5.8 Summary Matrix

Table 5.1 shows a Summary Matrix which incorporates the above principles for planning with the key climatic elements which are important in land use issues.

TABLE 5.1

PRINCIPLES FOR PLANNING MATRIX

CLIMATIC VARIABLES

	TEMPERATURE				PRECIPITATION					WINDS	SOLAR RADIATION
	Max., Min. Mean Seasonal	Frost Free Days	Heating Degree Days	Growing Degree Days	Mean Rainfall	Greatest Rainfall in 24 Hours	Mean Snowfall	Days with Rain (Probability) Days with Precipitation Days with Freezing Rain	Snow Cover	Speed Frequency Gusts	Days with Sunshine and Solar Radiation
Residential	H	H	H	NA	L	NA	L	NA	NA	H	H
Commercial	L	L	L	NA	NA	NA	NA	NA	NA	L	L
Industrial	L	L	H	L	NA	NA	L	H	L	L	H
Recreation	L	L	L	NA	L	L	L	L	L	L	H
Transportation (Pedestrian & Vehicular)	L	L	NA	NA	L	L	H	H	H	L	L

H - High Importance
L - Low Importance
NA - Not Applicable
(AES, 1979)

Conserving Energy by Planning with Climate

6.0 CONSERVING ENERGY BY PLANNING WITH CLIMATE

The direct conservation of energy is only one goal for the use of special design techniques to incorporate climatic factors in land use planning. Meeting other goals, such as increasing human comfort, saving money and decreasing environmental impacts may indirectly result in energy savings. The following chapter will discuss the various climatic factors and their effectiveness in making direct energy savings. Planners and decision-makers dealing with energy issues should make use of this information to identify critical climatic variables to be considered as part of a comprehensive energy conservation strategy.

6.1 Climatic Factors and Energy Conservation

6.1.1 Solar Orientation

Solar radiation is the most important climatic factor to consider in designing for energy conservation. It affects virtually every portion of building design, siting and orientation.

Controlling solar radiation is one of the best methods the design team can use to reduce energy consumption in a building. Basically, this control consists of maximizing solar energy during periods requiring heating (winter) and reducing to a minimum the solar energy entering the building during cooling periods (summer), especially in Southern Ontario.

Orientation of buildings and shading devices are the two most effective methods of controlling heat gain. The available estimates indicate that proper home orientation alone can reduce space heating demands by 10-15%. (See Table 6.1). To optimize the use of this free solar heat, the building needs to be well insulated and further improvements in energy conservation by using external shading devices to keep solar radiation out in the summer and

allowed in during the winter, and by the use of insulated shutters on the windows at night. The use of these design features has been estimated to reduce space heating energy requirements by over 50%; therefore, to maximize fuel savings, correct building orientation must be combined with Building Codes to encourage other energy conservation features.

TABLE 6.1

FUEL SAVINGS FOR DIFFERENT ENERGY CONSERVATING FEATURES ON 15 UNIT TOWNHOUSING PROJECT

	Savings $	Cumulative New Cost per year $	Savings %
Existing Cost of Heating		266	
Fuel savings due to orientation	33	233	12
Fuel savings due to improved insulation	44	189	19
Fuel savings due to insulated shutters	51	138	27
Fuel savings due to solar storage system	39	99	28
Fuel savings on domestic hot water with solar storage system	44	45	55

Source:

John Hix/Architect-Planner, June 1977, Study carried out for City of Toronto (Energy Report Frankel/Lambert).

Sunshine can also be used to replace internal lighting in many buildings. Artificial lumination is one of the major consumers of energy in commercial buildings. Sunlight can be coordinated with artificial lighting to improve the overall energy performance of a building. Diffused solar radiation is more desirable than direct radiation for natural lighting. It has been estimated that the reduction in total building energy consumption can be as much as 50% for heating, cooling and lighting with an appropriate combination of window and wall area (See Table 6.1).

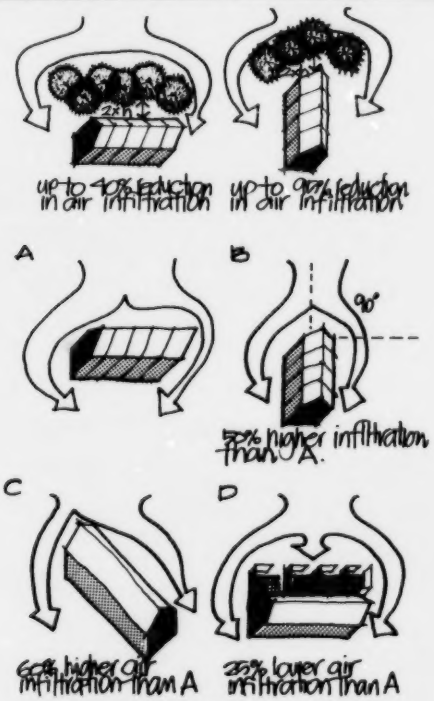
6.1.2 Wind Orientation

Controlling wind is another important climatic planning technique which can be used by planners to reduce building energy consumption. Strong winter winds increase infiltration and convection heat losses from buildings and cool summer winds can reduce air conditioning requirements in Southern Ontario. The correct orientation of groups of buildings has been shown to substantially reduce the infiltration of cold air (see Figure 6.1). Estimates indicate that heat savings of 15-20% can be achieved by reducing winter heat losses due to wind. (Underwood, McLellan, 1980).

Wind orientation can also be used to reduce energy requirements for air conditioning during the summer months, especially in Southern Ontario. This objective is more difficult to achieve since these winds may often be light and, therefore, not easily manipulated. However, allowing cool light breezes to move inland, rather than creating a wall of highrise structures along the lakeshore, is one method of promoting much needed ventilation. This is possible to achieve using standard land use planning techniques.

FIGURE 6.1

AIR INFILTRATION IN NON-SHIELDED ROWS



Source: RAIC, Fig.6.5.1.1.2

Control of wind is greatest near the earth surface and climatic planning techniques using terrain and vegetation can best act to control wind speed and direction in this zone. However, once buildings go above three or four storeys, surface control becomes difficult except by constructing more buildings of the same height. Therefore, for various land uses, the prime impact that the planner can have will depend on building height. The smaller the building, the more climatic techniques can be used to slow down winter winds.

6.1.3. Landscaping

Correct planting and vegetation can deflect winter winds and deciduous trees growing on the south side of a building will provide shade during the summer, thereby reducing heat gain.

The recent study of energy conservation by residential site planning has estimated that landscaping is capable of producing energy savings in excess of 6% of the total used for space heating. (Ministry of Housing, 1980, p.1.3).

6.1.4 Topographic Design

Topographic variation can affect building energy consumption because it may alter both the micro- and mesoclimatic conditions. White it is generally not possible to alter topographic conditions to conserve energy, planners should have regard for the specific effects on the climate of topographic variables, such as elevation, smoke, aspect, albedo, nature of surface, distance from water bodies and vegetation. The Royal Architectural Institute of Canada has developed a table which summarizes the topographical influences on climatological variables (Table 6.2). This table may be used by designers to assist in site selection or by energy planners to identify topographic effects upon the other critical climatic factors.

TABLE 6.2

TOPOGRAPHICAL INFLUENCES ON CLIMATOLOGICAL VARIABLES

	Minimum Temperature	Maximum Temperature	Heating Degree Days	Humidity	Wind Speed and Direction	Cloud Cover	Radiation	Rainfall	Snowfall & Snow Cover
Elevation	Inverse relationship	Inverse relationship	Increase with height	Fog moisture available to plants at greater heights	Increase speed with heights	Increases with elevation Fog also increases with height	Increases with height Outgoing rad remains same	Rain increases with height Proportion of rain of total precipitation decreases	Snowfall increases with height Wetness of snow decreases with height
Slope	Cold air drainage can be directed Direct relationship with speed of cold air drainage	Max. temp highest at bottom of slope in summer Variable location in winter	Higher in valley than in thermal belt on above slope	No direct influence	Angle influences the speed of movement of cold air at night Anabatic and katabatic flow	Increased with slope angle	Increases or decreases radiation depending on slope angle	Windward and leeward slopes will be wet and dry rain shadows respectively	Windward and leeward effects on snowfall
Aspect	Aspect less important at night as temperature controlled by flow of cold air	West slopes higher than east slopes South slopes higher than north slopes Valleys running N S & south facing slopes have highest max	North facing aspect will have higher HDD than south facing aspect	Absolute humidity not affected Relative humidity is affected	Will depend on direction slope is facing and wind direction e.g. windward or leeward	Extremely variable depending upon time of year air mass etc	Will be most on south facing & least on north facing	Windward or leeward - either increase or decrease in rainfall	Windward or leeward - either increase or decrease in snowfall Snow cover greatest in NE slopes
Albedo	Can increase or decrease min temperature considerably	Can increase or decrease max temperature considerably	Can increase or decrease HDD	Can increase or decrease evaporation & influence humidity	Can create pockets of ascending & descending air	Convective clouds predominate in the afternoon Layer clouds predominate after sunrise	Influences percentage of radiation absorbed	No direct influence	Can influence snow cover eg localized melting
Nature of Surface	Highest with grass then with bare soil Lowest with bare rock	Lower with grass than with bare soil Highest with bare rock	Comparison of snow surface can influence heating degree days	Short grass evaporation greatest after rain Water surface evaporation greatest on bright days & on days of drought	Roughness coefficient determines eddies & local currents	Low albedos can create convective clouds	High albedos reflect much radiation Low albedos absorb short wave & emit long wave	No influence on rainfall but considerable on evaporation perspiration, runoff, etc	No influence on snowfall but considerable influence on snow cover distribution
Water Bodies	Modified by nearness to water bodies is a function of water temp and size	Modified by nearness to water is a function of water temp and size of water body	Decreases with nearness to water bodies	Increased humidity	Usually increased by moving over water	Extremely dependent upon time of year	Can reflect & emit upwards onto slopes	Often increased near shore as winds pick up moisture pass over cold land Air condenses and precipitates	Often increased near shore as winds pick up moisture pass over cold land Air condenses and precipitates
Vegetation	Increase in min temp with increasing density	Decrease in max temp with increasing density	Within the vegetation canopy HDD are reduced The taller the vegetation the greater the influence	Increases humidity through evapotranspiration Depends on density of growth	Decreased wind speed with the vegetation canopy	No influence	Total incoming and outgoing radiation remains same but varies within the vegetation canopy	Rainfall not influenced but evaporation drainage etc are changed by vegetation	Snowfall not influenced but snow cover distribution and snow melt are
Hills and Valleys	Cold valleys & lower hill slopes Thermal belt on slopes above valley bottom	Max temp slow rate of rise in valley bottom Max temp highest on upper slopes	Highest in valley bottom & lower slopes except at great heights	Can trap moist air in valleys	Funnel effect, greater wind speed in valleys Cold air drainage channelled by valleys and obstacles	Cause increased cloudiness due to rising warm air and decreased temp	Can reduce daily incoming solar radiation	Windward and leeward slopes wet & dry respectively	Snowfall increased on upper slopes except where swept by winds

Table 2.1.4.T1
Topographical influences on climatological variables

Source: RAIC, Table 2.1.4.T1

Elevation will not have a significant impact upon energy conservation in most parts of Ontario. Slope, vegetation, hills and valleys may be used to channel cold air and will therefore affect heat loss in buildings. Aspect, albedo and nature of surface can affect incoming solar radiation and alter the amount of energy used for space heating and lumination. Finally, water bodies may moderate the microclimate of lakeshore areas to a depth of approximately 2-3 kilometres.

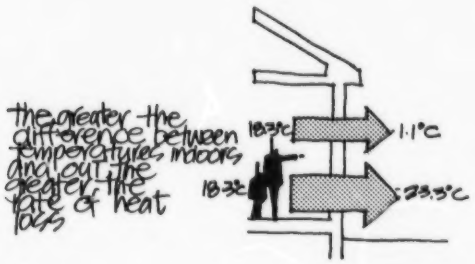
6.1.5 Temperature

Temperature acts in two ways to increase building energy consumption. In Ontario, the largest effect is through generating a space heating demand whenever mean daily air temperatures fall below 18°C. The second energy demand is for air conditioning caused by summer hot air temperatures in combination with high humidity levels. Due to cooler temperatures and generally lower humidity levels, Northern Ontario air conditioning requirements are minimal.

The temperature outside of buildings may be manipulated by avoiding valley bottoms and depressions where cold air collects at night, as temperatures may be 5-7°C colder in these hollows than in the surrounding terrain. In addition, it may be possible to manipulate the urban heat island by blocking the winds which may break it up in the winter and encouraging summer breezes to decrease its size. The heat island may result in a temperature difference of 3-5°C in certain parts of urban areas.

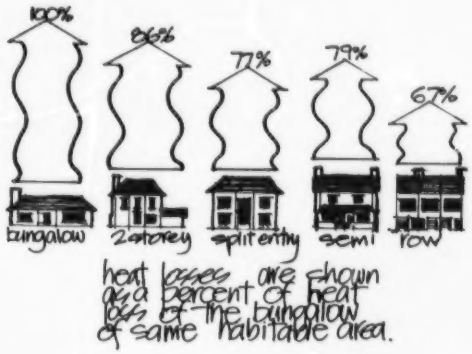
A more promising means of controlling the effect of temperature upon building energy consumption is by reducing the transmission of heat through building walls (see Figure 6.2). This is accomplished by reducing the surface of the building which is exposed to different temperatures and also by reducing the rate at which heat flows through the building walls and roof. These effects can be minimized by designers adopting more compact building forms and higher insulation standards. A typical row townhouse is estimated to consume 67% of the energy used by a standard single family dwelling (See Figure 6.3).

FIGURE 6.2
HEAT LOSS THROUGH BUILDING WALLS



The greater the difference between temperatures indoors and out, the greater the rate of heat loss.

FIGURE 6.3
RELATIVE HEAT LOSSES BY DWELLING TYPE



6.1.6 Humidity

Humidity only influences building energy consumption during periods of the summer where air conditioning is required. This predominantly occurs in Southern Ontario where high relative humidities in combination with high air temperatures cause an air conditioning demand. Due to the nature of the atmospheric conditions that give rise to high humidities and high temperatures, it is possible that surface modifications, due to land use planning, may have little influence on overlying atmospheric humidities. The most promising method of reducing air conditioning requirements is probably through reducing temperatures using a variety of the techniques described above. Therefore, control of humidity is a minor factor in terms of energy conservation.

6.2 Critical Climatic Factors for Energy Conservation

The three most important climatic factors for energy conservation are:

1. Orientation for Solar Radiation
2. Temperature
3. Orientation for Prevailing Winds.

These factors were chosen because they have the potential to effect significant energy savings, they are capable of being implemented using standard planning techniques and they do not require major changes in personal behaviour or standards of living.

Several municipalities in North America have already adopted solar orientation guidelines as a part of their planning process and significant energy savings have been demonstrated. Case studies in Brampton, Ontario, have indicated that the use of solar orientation can be incorporated in the planning process without adding to the cost of building. As the user will receive the benefits of solar orientation throughout the life of the building without any action on their part, this climatic planning technique must be considered one of the most important available to planners.

Higher insulation standards for new construction are being adopted throughout Ontario and some progress is being made in retro-fitting existing buildings. While these higher standards do add to the price of new housing, the benefits obtained in fuel savings far outweigh the costs and province-wide codes for insulation should eliminate price competition from construction of sub-standard buidlings. The adoption of more compact building types does not require a major change in consumer preferences, especially if the amount of space available to the users remains approximately constant.

Wind orientation is similar to solar orientation in that it costs very little to implement, is effective in reducing building energy demand and is appreciated by building users.

6.3 Critical Land Uses for Energy Conservation

Residential areas are the most important land use for designing with climate for energy conservation. Residential uses consume the majority of the land in most urban areas and use 20% of Ontario's total energy consumption (see Figure 6.4). Most residential buildings are small enough that shading in winter and overheating problems in summer are not too difficult to overcome. In addition, they are occupied on a 24 hour basis in many areas to that responses by the occupants such as opening drapes on sunny days and closing insulating forms at night can greatly effect building energy use.

Commercial and industrial buildings may also benefit from energy savings by designing with climate. The correct solar orientation of commercial buildings with large areas of windows (such as offices) has been shown to result in substantial energy savings. In addition, the adoption of higher insulation standards and better building techniques to reduce air infiltration has been shown to substantially reduce space heating requirments in commercial and residential buildings.

Design techniques which use buildings or vegetation to block winter winds and to provide shade and summer breezes are appreciated by the occupants of all types of land uses and should simply be adopted as standard planning techniques throughout Ontario.

FIGURE 6.4
ENERGY USE BY
ACTIVITY SECTOR

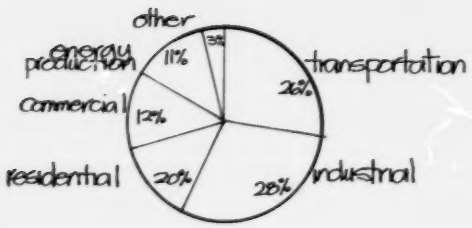
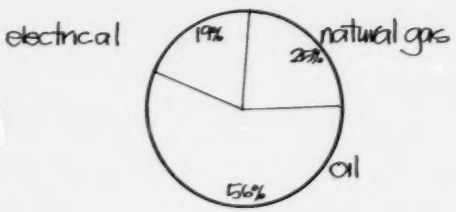


FIGURE 6.5
ENERGY SOURCES FOR
THE RESIDENTIAL SECTOR



6.4 The Effects of Age of Development

6.4.1 Existing Development

It is difficult to use new design techniques to effect major changes in energy conservation across an urban area because the street pattern and building types which already exist were not necessarily built to conserve energy. Thus, designers must attempt to preserve those aspects of settlements which "accidentally" act to conserve building energy use (such as parkland or heat island formation), and, when redevelopment takes place, ensure that the potential for energy conservation forms an important part of any plan.

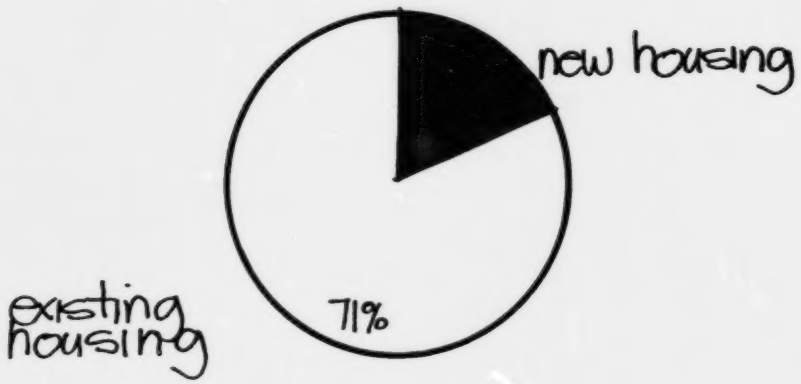
The redevelopment of deteriorated waterfront areas in several Ontario municipalities is a prime example of how such a program could be followed. Low buildings with high site coverage could be used to allow breezes from the lake to ventilate downtown areas. In redevelopment projects in other central areas, the site planning process can be used to ensure that new buildings do not critically shade other structures especially those with south facing glass. Finally, redevelopment and rehabilitation programs in existing residential areas should emphasize the upgrading of insulation, the addition of south facing windows, energy conscious landscaping, and the addition of greenhouses to capture solar heat.

6.4.2 New Development

The difficulties involved in attempting to retrofit an established urban area make a powerful case for energy conscious planning to be adopted in all new development. Results of the land use planning which is currently being carried out could be part of the urban structure for at least 20-60 years (Figure 6.6). Although only a small percentage of an urban area consists of new development in any given year, a considerable amount of energy could be conserved over its lifetime by using proper design techniques.

FIGURE 6.6

HOUSING BUILT BETWEEN 1980 AND 2000
AS A PORTION OF ALL HOUSING



Implementation Strategies

7.0 IMPLEMENTATION STRATEGIES

The theory of energy conservation through climate-concious land use planning must be applied to realize the potential benefit. The methods are often innovative and not familiar to developers, councils and the general public. This chapter presents a brief outline of opportunities that planners could pursue to initiate implementation strategies at all levels. It is here that many of the greatest difficulties lie and thus the greatest challenge to improve the planning process.

7.1 Opportunities for Municipalities

The primary documents controlling development in a municipality are the Official Plan and the Restricted Area (Zoning) By-laws. Implementation of land use planning policies that will realize energy conservation will therefore appear as amendments to these controlling documents. However, planning staff must provide Council with a clear set of guidelines and subsequent policies, as many of these policies will be innovative and their true benefit only realized over the long-term.

As provided in Section 35a, of the Planning Act (RSO 1970, Ch.349) a municipality can regulate the design, landscaping, materials used, etc. for any proposed development, by using site plan control. Through this vehicle, the municipality can implement many of the energy saving measures outlined in this report.

7.1.1 Wind

A number of major Canadian cities including Ottawa, Toronto and Calgary have adopted wind policies to control urban wind conditions. The City of Calgary currently requires all new developments to demonstrate that no adverse wind conditions will result prior to issuing building permits. While testing could be required for development in urban centres where wind problems can be

severe, consideration could also be given to wind conditions in suburban and rural development proposals. Major testing facilities in Ontario are located in London at the Boundary Layer Wind Tunnel Laboratory and in Ottawa at the National Research Council.

Maintaining the appropriate distance between buildings and restricting building size in the direction of cooling summer winds can be controlled by municipal legislation.

7.1.2 Solar Radiation

To protect the potential for utilizing solar radiation, municipalities could pass by-laws limiting building size and height where shading is especially critical. This will be most important in northern Ontario where the low winter sun causes long shadows. Shadow diagrams for new buildings at different times of the year should also be required. Regulation of industrial pollution and location of industrial plants with high emissions will influence the available solar radiation.

7.1.3 Temperature

Consideration could be given to the regulation of building height and the location of industrial and vegetated open spaces as it has been shown that these land uses influence air temperature. Higher density of developments such as apartments and townhouses use less energy than single family dwellings of equal area because smaller surface areas on external walls are created.

Throughout the development approval process, municipalities must endeavour to introduce legislation that will encourage energy conscious land use planning and make energy consumption a basic consideration for development proposals. To support this approach, municipal planners must provide a concise set of guidelines and development criteria to be considered and adopted by Council.

7.2 Opportunities for Innovative Design

In trying to achieve attractive and acceptable plans together with a reduction in energy consumption, a designer will often consider an innovative approach. Many innovations will yield substantial returns if initial hesitations towards changes in the norms can be overcome. A move towards more compact development in commercial and residential areas will make buildings less susceptible to climate and more efficient in utilizing energy. Development of mixed use facilities can provide some protection from the weather that is not offered by dispersed buildings.

Land use planning in conjunction with legislation can eliminate the need for some public buildings by encouraging the use of schools, libraries, etc. during off-hours for other community functions. Proper designs can also permit simple conversion from one use to another. Building designs that utilize alternative energy sources such as solar, wind, and geothermal power could be encouraged and their development facilitated.

In northern Ontario communities where heating is required on a year-round basis, the use of district heating facilities, and where extreme climatic conditions exist, the development of mega-structures that house all community uses in one complex could be considered. Where the climate is not quite so severe, industrial buildings can be used as a barrier to protect residential areas from cold winter winds. Where industries and/or energy producers

release large amounts of heat as waste, this can be directed to nearby consumers. A working example of this theory is the Bruce Nuclear Power Development which supports agricultural and industrial development.

Many Ontario towns border on large bodies of water which have been shown to influence the mesoclimate. In planning redevelopment and new buildings in the vicinity of the waterfront, the climatic benefits inherent in this location should be incorporated in the design.

Where unique topographic and climatic conditions combine to produce an attractive location for development from an energy conservation viewpoint, encouragement should be given to innovative designs that can best utilize these potentials.

7.3 Procedures for Incorporating Climatic Data into The Planning and Design Processes

Land use planners are constantly required to select and recommend the appropriate location for development to take place and are often required to comment on the proposed designs. This evaluation could consider, and recommend, the site location and design that will minimize energy consumption. To obtain this information the following steps could be taken.

1. Use the macroclimatic information presented in Chapter 3 to determine the climatic characteristics of the appropriate region. Site specific data should be obtained for the closest climate observing stations (see Section 3.5).

2. Apply the information on topographical and urban effects (Chapter 4) to identify opportunities for energy conservation at the actual or potential building site.

3. Examine the various sites for the building or development and choose a site that provides the maximum energy gain from natural energy sources and the maximum energy reduction from climate-based energy conservation strategies.

4. Based on the knowledge of the general climate and the energy conservation methods that can be designed to take advantage of these climatic elements, develop a building plan and landscape design to minimize energy losses.

5. Recommend that development be built according to this plan.

(Source: RAIC, 1979)

7.4 Land Ownership and Tenure

Implementation of energy conservation programs is likely to be inhibited by the type of ownership and tenure of the area under consideration. Improvements to public buildings can be initiated by Council to reduce municipal spending and provide an example to the local residents. The private sector, however, can only be encouraged as legislated improvements are unlikely to be acceptable. In a similar manner, renters may agree with energy conservation objectives but be unwilling to invest money in a rented property.

Where new development is proposed, the municipality will have a greater opportunity to encourage energy consious design and planning. Until legislated or proven cost-effective from the developer's viewpoints, these areas will still be subject to negotiation. Publicly developed areas and demonstration projects should, however, meet with less resistance and allow greater freedom for innovative design.

7.5 Educational Programs

Municipal land use planners could also prepare concise position papers on energy conservation for review by municipal officials. A thorough understanding of these issues will provide municipal officials with a background to evaluate energy policy proposals.

A key component in the implementation of innovative land use planning policies is to inform and educate developers, builders and the general public. Public presentations and forums will provide an opportunity to familiarize the public with energy conservation objectives and how they can benefit from participating. These meetings will not only improve common knowledge on energy conservation but also provide the basis for future support for energy conservation legislation.

Effort could also be made to inform local developers and design consultants of the municipality's position and attitude towards energy conservation through land use planning. The municipality could also encourage developers and design consultants to incorporate energy saving measures in their buildings and developments.

Conclusions

8.0 CONCLUSIONS

While some theories of energy conservation through land use planning with climate have been proven by demonstration projects, others have yet to be confirmed. These applications often seem remote and unrelated to the local conditions and problems faced by municipalities on a daily basis. This chapter briefly addresses the question; "What can we do?" and puts forward some ideas and actions for consideration by planners, developers and governments.

8.1 What can Planners do?

Despite the fact that final decisions regarding planning matters are usually made by elected officials, professional planners play a significant role in directing and influencing these decisions. Planners should strive to keep abreast of information in the energy field and encourage their municipalities to adopt energy policies and implement information programs. With a continually growing volume of information available in the energy field, planners may wish to obtain general publications such as this one. To obtain information or answers to general questions on energy conservation it is recommended that planners contact the Ministry of Energy at the following address.

Ministry of Energy
Conservation and Renewable Energy
10th Floor
56 Wellesley Street West
Toronto, Ontario
M7A 2B7

Telephone: (416) 965-9299

Planners must encourage and promote energy conservation in land use planning through consideration of climatic information with municipal staff, council members, developers and the general public.

8.2 What can developers do?

To demonstrate the advantages of building on a particular site, developers should include energy analysis in their design process. An explanation to Planning Committee and Council of how energy savings can be realized will augment the information provided by the planning staff. In municipalities with no planning staff, the developer or his consultant, may be the primary source of information on energy conservation. Under these conditions the developer's role may well expand to include assistance in the development of energy guidelines and policies. Developers should also participate in pilot projects and test applications to demonstrate savings.

8.3 What can government do?

At the local level, municipalities can encourage new development and redevelopment proposals to consider climatic factors and their influence on the energy consumption. This can be done informally through the preparation of guidelines or formally through policies in the official plan, modification to the zoning by-law, and development incentives for energy-efficient designs. Council might also ask planning staff to obtain climatic information for the municipality and recommend appropriate energy policies. Applications that require site plan control approval should be subject to a review of how well the design and building siting reflects local climatic conditions.

Provincial government officials should prepare guiding policies for the local municipalities and undertake research in areas that have not received sufficient attention. In undertaking this report, deficiencies have been noted in the following areas:

1. Solar radiation, in particular the effect of slope and building orientation on reducing winter energy potential.

2. The influence of terrain, water bodies, vegetation and urban areas on air temperature.

3. The local influence of terrain, vegetation, and urban areas on wind speed and direction.

4. How humidity can be modified and influenced by various land use patterns.

5. Site specific studies that illustrate the extent to which modifying the microclimate of an area influences energy consumption.

8.4 The Importance of Planning with Climate for Energy Conservation

International developments over the past decade have heightened our awareness of the finite limits to fossil fuel resources. Combined with rising prices and a continued interest in the state of the environment in which we live, the limited availability of fossil fuels has provided the impetus for interest in energy conservation.

The relative importance of the scale of climatic information to decision-making at different levels of planning has been summarized by Lacy (1972) and is presented in Table 8.1.

TABLE 8.1

THE IMPORTANCE OF CLIMATIC SCALE TO PLANNING

	Macro-Scale (regional)	Meso-Scale (Including urban)	Micro-scale
Regional Planning	Dominant	Important	Less Important
Town Planning	Important	Dominant	Important
Site selection and building design	Important	Important	Dominant

The relationship between energy consumption and climate is a predictable one as climatic conditions in Ontario are unlikely to change significantly in the next twenty years. As population increases, total energy consumption may rise but per capita usage will probably decline. With a temperate to cool climate, Ontario has

much to gain from planning with climate and realizing substantial energy savings. Many applications for conserving energy through recognition of climatic conditions have been proven and are in limited use throughout the province. Planners and politicians must develop this knowledge for wider application to realize the potential savings available today and more importantly, in the future.

GLOSSARY OF TERMS

A.E.S. - Atmospheric Environment Service

Albedo - The ratio of the amount of solar radiation reflected by an object or surface compared to that solar radiation received upon it.

Anabatic - An up-slope or up-valley wind.

Anemometer - An instrument used to measure wind speed.

Anticyclone - A center of high pressure, usually associated with fair weather.

Anthropogenic - Man made heat (due to combustion of fossil fuels) released into the atmosphere.

Convection - Heat exchange through mixing of the atmosphere.

Cooling Degree Day - Similar to heating degree days in concept except that these are accumulated when hourly temperatures exceed 24°C. Since humidity also influences air conditioning requirements, this can be accounted for with HUMIDEX calculations.

Cosine (Cos) - A mathematical relationship from trigonometry, such that:

Cyclones - A center of low pressure, usually associated with poor weather.

Evapotranspiration - The combined water loss from evaporation off water and soil surfaces and transpiration losses from vegetation.

Fetch - The upwind distance of an uninterrupted water surface. More generally, the distance upwind of any uninterrupted surface.

Heating Degree Days - The difference between the mean daily temperature and 18°C. For instance, if on January 1, the mean daily temperature was 0°C, then 18°C-0°C = 18 heating degree days. These daily totals are accumulated throughout the year and the annual total indicates the amount of heat that must be gained either by burning oil, natural gas, wood or obtained from the sun.

Humidex - A measure of human discomfort which is determined by taking dry bulb temperatures and adding to it a factor accounting for the moisture present in the air.

Infiltration - The movement of outside air through building cracks and ill-fitting doors and windows, therefore increasing building heat loss, especially under windy conditions.

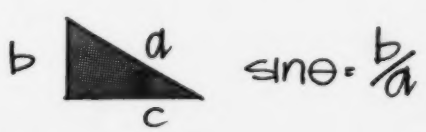
Isobar - Lines or equal pressure that often appear on weather maps.

Katabatic - A down-slope or down-valley wind.

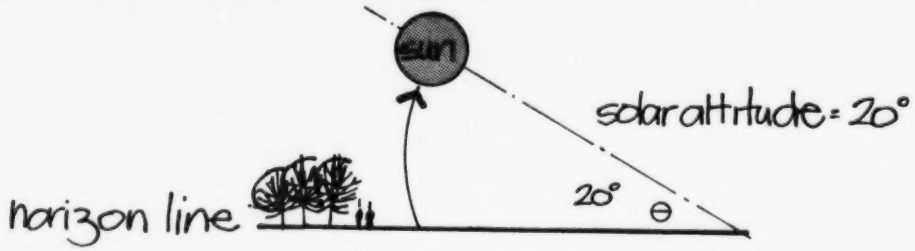
Microclimate - The climate of the lowest layers of the Earth (surface and soil) - Atmosphere system.

Psychrometer - An instrument for measuring atmospheric humidity. Consists of 2 thermometers, one covered with a wet muslin wick (the wet bulb thermometer). The other thermometer, the dry bulb, simply measures air temperature. The difference in temperature between the 2 thermometers is related to the amount of water vapour in the atmosphere.

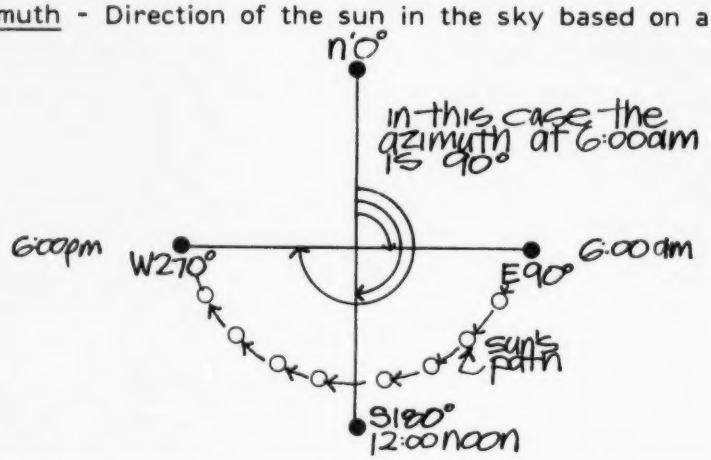
Sine (Sin) - A mathematical relationship from trigonometry, such that:



Solar Altitude - The angle of the sun above the horizon.



Solar Azimuth - Direction of the sun in the sky based on a circle (360°).



Solar Declination - That latitude where the sun is directly ovehead.

Solar Heating (Active) - Utilizing heat from the sun through heat storage systems. More complex than passive solar design since a medium like water or air must be circulated between a solar collector and the storage area.

Solar Heating (Passive) - Utilizing heat energy from sun to offset, to some extent, the need for auxillary heating systems. Relies on using windows on the south and east face of a building to maximize the absorption of solar radiation within the building.

Solar Radiation - Energy from the sun that arrives at the earth's surface as electromagnetic waves. Most of this energy is in wavelengths between .15 - 3 microns (2 micron = 10^{-6} metres).

Stevenson Screen - A white louvered wooden box placed 1.2 - 1.8 m above a short grass surface. Used to house thermometers or a thermograph. Designed to measure regional air temperature rather than that due to local surface conditions.

Tangent (Tan) - A mathematical relationship from trigonometry, such that:

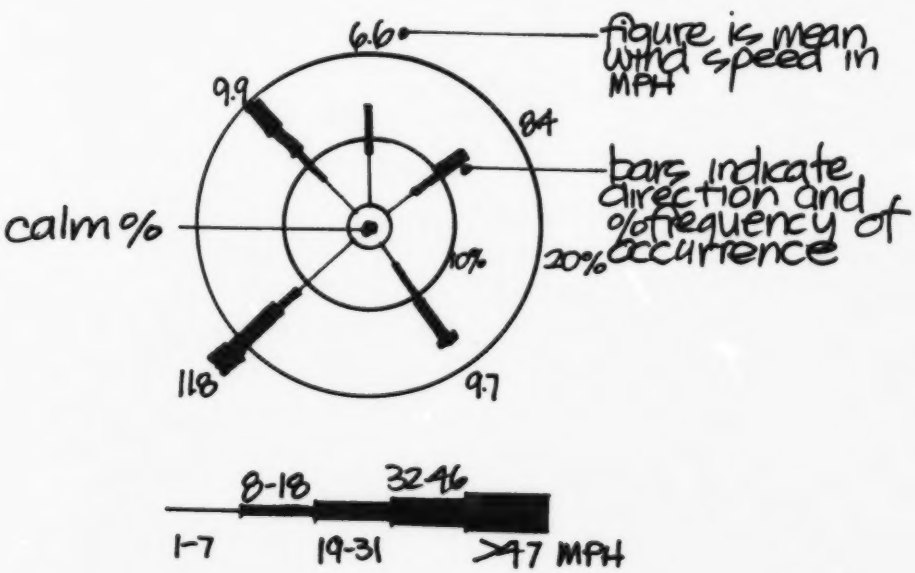
$$\tan\theta = \frac{b}{c}$$

Thermal Belt - That zone on a slope that is located just above the area where cold air accumulates due to cold air drainage.

Turbidity - Any atmospheric condition which reduces the ability of the atmosphere to transmit solar radiation.

Urban Heat Island - The increase in temperature generally found in most urban areas when compared to nearby rural environments.

Wind Rose - A method of displaying wind speed and direction.



REFERENCES

1. American Society of Landscape Architects, Landscape Planning for Energy Conservation, Washington : Environmental Design Press, 1977.

2. Bach, Wilfred. "Urban Climate, Air Pollution, and Planning" Ch.4 in Urbanization and Environment: The Physical Geography of the City, T. Detwyler and M. Marcus (eds.), Belmont, California, Duxbury Press, 1972.

3. Bach, Wilfred. "7 Steps to Better Living on the Urban Heat Island", Landscape Architecture, January 1971.

4. Bernatzky, Aloys. "Climatic Influences of the Greens and City Planning:. Anthos, Vol.5, No.1, 1966.

5. City of Brampton, Energy Conservation in Land Use Planning, February 1979.

6. Brown, D.M., et al. The Climate of Southern Ontario. Environment Canada, Atmospheric Environment Service, 1974. Climatological Studies No.5.

7. Chandler, T.J. Urban Climatology and its Relevance to Urban Design, New York : World Meteorological Organization, 1976. Technical Note #149.

8. Chapman, L.J. and M.K.Thomas, The Climate of Northern Ontario, Environment Canada, Atmospheric Environment Service, 1968. Climatological Studies No.6.

9. D'Agostino, S. et al, Climate and Energy Conservation, Environment Canada, Atmospheric Environment Service, Report SSO-79-17. September 1980.

10. De Chiara and Kippelman, Site Planning Standards, New York : McGraw Hill, 1978.

11. City of Edmonton, Planning Department, Considerations for Pedestrian Level Wind Conditions in Downtown Edmonton, December 1979.

12. Environment Canada, Workshop on Applications of Meterology to Design and Planning Urban Facilities in Ontario, Atmospheric Environment Service, Environment Canada, Internal Report SSU-78-12, December 1978.

13. Foster, Ruth F., Landscaping that Saves Energy Dollars, New York: David McKay, 1978.

14. Greenland, D. Aspects of the Mesoclimatology of the Toronto Area, Environment Canada, Atmospheric Environment Service, 1977. Climatological Studies No. 29.

15. Institute for Rational Design, Design and Control of Residential Development in Urban Communities, New York, 1976.

16. Kuhn, Eric. "Planning the City's Climate" Landscape. Spring 1959.

17. Lacy, R.E. Climate and Building in Britain, London, Her Majesty's Stationery Office, 1979. Building Research Establishment Report, Department of the Environment.

18. Laidlaw, K.E. and L. Lipovenko, Planning with Climate in Southwestern Ontario, Environment Canada, Atmospheric Environment Service, Report SSO-79-8.

19. Lang, R. and A. Armour, Energy Conservation and the Municipal Planner, Ottawa : Development of Energy Mines and Resources, 1980.

20. Lansberg, H.E. Weather, Climate and Human Settlement, Special Environmental Report #7. World Meteorological Organization, Geneva, Switzerland, 1976. WMO # 448.

21. Lowrie, M. Introduction to Landscape Architecture, New York : Elsevier, 1975.

22. Lynch, K. Site Planning, Boston : MIT Press, 1971.

23. National Research Council, Climatic Information for Building Design in Canada, 1970. Supplement No.1 to the National Building Code.

24. "New Communities in Canada", a special edition of CONTACT, Volume 8, No.3, August 1976. Part III, "Resource Based Settlements in the North".

25. Olgyay, Victor, Design With Climate, Princton, N.J. : Princeton University Press, 1963.

26. Ontario Ministry of Energy, Energy Efficient Community Planning: Bibliography, June 1980.

27. Ontario Ministry of Housing, A Guide to Residential Planning and Design in Small Communities, 1980. Chapter 2.

28. Ontario Ministry of Housing, Residential Site Design and Energy Conservation, Volume I, January 1981.

29. City of Ottawa, Planning Branch, Considerations of Wind Problems in the Downtown Core, 1977.

30. City of Peterborough, Planning Department, Climatic Considerations in Urban Development, December 1978.

31. Regional Municipality of Hamilton Wentworth, Planning for Low Density - A Solar Approach, Planning Department, 1980.

32. Royal Architectural Institute of Canada, Energy Conservation Handbook. Ottawa : RAIC, 1979.

33. City of Toronto, Central Waterfront Planning Committee, Climate, January 1976.

34. Underwood, McLelland Ltd. Energy Conscious Landscape and Urban Site Design, Saskatoon : City of Saskatoon, 1980.

35. "Wind Environment Around Tall Buildings". Building Research Station Digest, No.141, May 1972.

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